THE

JOURNAL OF ANATOMY AND PHYSIOLOGY

NORMAL AND PATHOLOGICAL.

CONDUCTED BY

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PROFESSOR OF ANATOMY IN THE UNIVERSITY OF CAMBRIDGE;

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Journal of Anatomy and Physiology.

PRESTERNAL FISSURE UNCOVERING THE BASE OF THE HEART.

By George A. Gibson, M.B., D.Sc. Edin., *Assistant Physician*, and Henry Malet, B.A., M.B. Dub., *Resident Physician to the Birmingham General Hospital.* (Plate I.)

Malformations of the sternum are not very uncommon, and are caused usually by arrest of development. A most interesting and instructive example has recently come under our notice, and appears well worthy of being recorded. Before entering upon a description of the case, however, it may be well to glance briefly at one or two phases of sternal development.

Rathke has shown that the first seven ribs of either side, after passing round the visceral laminæ of the embryo, are united at their anterior ends by a continuous strip of cartilage, and that the two lateral strips afterwards join from above downwards to form the non-segmented cartilaginous sternum. During the conversion of the cartilage into bone the presternum has usually only one ossific centre, and if two are present they both occupy the middle line, one being placed above the other; the first piece of the mesosternum is very rarely developed from more than one centre, but the remaining segments have frequently two lateral centres of ossification, and the metasternum is extremely irregular in its development.

Sternal fissures must be regarded as traces of the primordial median division, and occur in the relative order of frequency which a consideration of development would lead us to expect. Irregularities of the ensiform cartilage are exceedingly common,

and a slightly cleft condition of the lower end of the gladius has often been described. An aperture, or *foramen sternale,* in the the body of the bone is frequent in the dissecting-room, and occupies the lower portion of the gladius. Much more rarely is the condition of fissure of the manubrium, about to be described, met with, and, as in the case of Herr Groux, the sternum has been seen cleft in its whole length. The classic memoir of Dr Allen Thomson gives an admirable description of this latter condition;[1] and as he enters fully into the anatomical and physiological phenomena exhibited by those fissures previously recorded by competent observers, it is needless for us to go over the same ground again. The brief notice of the autopsy of Herr Groux which has reached this country appears to bear out Dr Thomson's description to the full.

The sternal deficiency which is the subject of the present paper exists in a young man, aged twenty-one, of muscular frame and athletic habits, who has never suffered in the least from his deformity. He has a second mesial malformation, in the shape of a strip of skin extending upwards from the umbilicus for 3 inches, in all of which distance it is attached to the abdominal wall, and expanding into a fan-like bundle of wrinkles. A distinct depression occupies the superior sternal area and opens above into the neck, as a deep fossa, between the clavicles and sterno-cleido-mastoid muscles, which stand out in strong relief. The floor of this depression moves slightly with respiration, and there is a marked pulsation in the left lower portion. Tactile examination shows this depression to be due to a complete absence of the bony chest-wall, the want of which is partially compensated by the existence of a strong membrane stretched across the fossa. The dimensions of the fissure are as follows:—the inner ends of the clavicles are $2\frac{1}{8}$ inches apart superficially, and $1\frac{7}{8}$ inch deeply; they rest upon the two lateral divisions of the manubrium, which are at first $1\frac{5}{8}$ inch from each other, and at the level of the second rib $1\frac{7}{8}$ inch; from this point they incline towards the middle line and meet in osseous union at the level of the upper surface of the fourth rib. The two lateral divisions of the sternum are each $\frac{7}{8}$ inch broad at the second interspace, and $\frac{3}{4}$ inch at the third. The lower part of the fissure, from the

[1] *Glasgow Medical Journal,* April 1858, p. 48.

lower border of the third to the upper border of the fourth rib, is occupied by a dense membrane or cartilage $\frac{3}{8}$ inch deep, presenting a crescentic border superiorly; the ensiform cartilage is divided into two spines, of which the left is merely a mammillary process, while the right is an inch long. The clavicles are strong and well-formed, measuring an inch both vertically and antero-posteriorly; the sternal origins of the sterno-cleido-mastoid muscles pass down in front of the clavicles, and are attached to either sternal division, they, as well as the sterno -hyoid and -thyroid muscles, being widely separated in the neck.

From the crescentic border described above a strong but lax membrane arises, which is attached to the sides of the fissure, and extends to the level of the middle of the first rib. The upper border of this membrane is doubly lunated, the left curve being slightly shorter than the right, so that they meet in an angle slightly to the left of the middle line, at which point the membrane becomes continuous with a strong cord-like band of fibrous tissue, ascending to the cricoid cartilage, with which it is closely connected. The act of swallowing draws upon the band and makes the membrane tenser, and if the finger be pressed firmly upon this latter the cricoid cartilage is dragged down a little. When the hands are forcibly pressed together the cleft becomes perceptibly but very slightly wider above, and the same effect is produced by pressing the forehead strongly against any obstacle. The osseous relations and the membrane are delineated in Plate I., which gives a faithful representation of the man's appearance.

A line drawn from the middle of the second left intercostal space at its sternal end to a similar point in the third right, cuts off, below and to the left, the strongly pulsating portion of the membrane; at and above the superior border of this structure the cervical vessels visibly pulsate. On deep expiration the membrane sinks and renders all these pulsations more marked, while deep inspiration has a contrary effect. Any violent expiratory effort causes a great inflation of the membrane, which bulges out much above the level of its borders; this swelling passes out some distance into the neck. After deep inspiration the form of this swelling can be made out very well, especially when the man makes an expiratory effort with the glottis closed.

The swelling in the fossa is marked by two sulci running towards each other from the lower edge of the clavicles, and meeting at a point 1½ inch below them, from which another depression runs towards the pulsating area below and to the left. The swelling caused by inspiration is therefore trilobate, with an upper, a small left, and a large right lobe. The right and left are clearly resonant on percussion, but the upper is muffled.

When in the horizontal position the apex beat cannot be seen or felt, but when upright it is found in the fifth interspace, 3 inches from the middle line. The cardiac dulness in the left parasternal line begins at the third costal cartilage, and along the fourth right rib it commences at the sternal edge. The pulsation seen in the vessels of the neck is double, owing to the effect of the closure of the semilunar valves being both seen and felt. The action of the heart is perfectly regular, and the pulse 76 per minute.

The pulsation in the lower part of the fossa is very peculiar The "state of rest" here is a prominent degree of fulness; the cycle commences with a sudden increase of tension, followed by a swift wave-like subsidence downwards; this in turn is succeeded by a sharp short impulse, after which there is a swift return of the swelling again. Light palpation conveys the same impression, the sharp short impulse being especially marked; after the rise in tension the sinking of the swelling is distinctly vermicular, and running from above downwards. The touch must be very light, as the least degree of firm pressure brings on a state of extreme arhythmia if persisted in for a few seconds.

At the apex of the heart the sounds on auscultation are perfectly natural; over the tricuspid, aortic, and pulmonary areas they are also normal. By means of the double flexible stethoscope the sounds of the pulsating area in the fissure have been very carefully analysed. They are, of course, better heard when the man reclines on a couch. Accompanying the increased tension which begins the cycle is a faint hushing murmur, immediately followed by the first sound, beginning with and lasting until the end of the downward subsidence, and accompanied by a soft low murmur; the short sharp impulse coincides with the second

sound, which is extremely loud, and along with the return of the swelling there is a scarcely audible hum.

We have taken advantage of the graphic method in order to register the impulses communicated to the membrane, and have in this manner accurately determined both the absolute form and the relative rhythm of these impulses. The instrument used for this purpose is the *direct* cardiograph, which we specially modified to suit the requirements of the case. Although the evidence collected by means of two senses cannot safely be compared when an exact result is wished, we can nevertheless judge approximately in this way of the synchronism of two impulses, or of impulse and sound. Placing a finger upon the carotid artery, and watching the lever of the cardiograph whilst in motion, the arterial pulse appears to coincide with the swift fall of the lever; still watching the movements of the lever, and listening to the heart sounds with the binaural stethoscope, the first sound is clearly synchronous with the abrupt rise of the lever to its highest elevation, and lasts until it descends to the lowest point, the sharp impulse which follows being exactly coincident with the second sound.

Fig. 1 is a faithful copy of the tracing obtained from the pul-

sating area. It shows almost perfect regularity of the heart's action, and exhibits also the undulations caused by the rise and fall of intrathoracic pressure during ordinary respiration. Following the slight rise at *a* is the ascent to *b* spoken of above, with which the first sound begins; this in turn being succeeded by the swift descent of the lever caused by the quick vermicular subsidence over which the first sound lasted; the abrupt rise at *c* is due to the sharp impulse accompanying the second sound.

By means of the direct differential cardiograph, fig. 2 was obtained, in which the upper tracing is taken from the carotid artery at its origin from the aorta, about the upper part of the membrane, and the lower tracing from the pulsating area of the fossa. In this figure it is clear that the arterial impulse coincides

exactly with the falling away of the pulsating tumour, for as the lever showing the arterial movements rises to *b'*, the one in connection with the tumour makes a sudden descent from *b*. The rise at *c'* agrees in rhythm with that at *c*, which we have seen to accompany the second sound. A word may be said about the

arterial tracing. The main systolic wave b' is of course quite intelligible, and the series of waves culminating in c' are merely the katacrotism of all arterial tracings; the four faint waves beginning with a' require explanation however, and seem to be caused by tremors conveyed up the membrane from the pulsating area below. The number of these little waves agrees with the number of those on the tracing below.

The starting-point in the cycle of movements, as shown in fig. 1, is *a*, which, from its relative rhythm, must be caused by the auricular systole. The ascent of the line which follows appears to be brought about in this way:—immediately after the contraction of the auricles, the ventricles become tense, gather themselves together, so to say, and almost instantaneously begin to expel the contained blood; in the first of these processes a sudden shock is given, which causes the elevation to *b*, and at once thereafter the cavities empty themselves, and therefore allow the lever to fall suddenly, tracing the descent from *b*. That this view is correct, appears to be proved by the comparison of the upper and lower tracings in fig. 2, which shows that the emptying of the ventricles coincides with the filling of the artery. The abrupt but small rise at *c* can only arise in one way. Coinciding as it does with the diastolic shock and second sound, and being synchronous with the katacrotism of the arterial tracing c', it marks the commencement of diastole, and is caused by the weight of the blood falling on the semilunar valves, and transmitted thence through the tissues of the heart. In every good apical cardiogram the same diastolic impulse is shown. Succeeding this little rise, which so clearly marks the commencement of diastole, is the filling-up of the heart by the blood entering during its relaxation, which causes the ascent of the line to *d*. A great deal of difficulty besets the attempt to explain the further elevation of the line to *e*, as well as the succeeding wavelets shown by the sinking of the line from that point. The only rational hypothesis which we can offer is that the line rising to *d* shows the filling-up of the auricles by the surcharged *venæ cavæ* and *pulmonales*, whilst the succeeding elevation to *e* is due to the filling of the ventricles, after which the heart becomes quiescent. It is possible that the elasticity of the heart, aided by the uncoiling of its muscular fibres, may

have something to do with the formation of these waves, but, as we differ in opinion upon this point, we cannot propose any hypothesis.

With regard to the determination of the particular part of the heart which is the cause of the pulsation, there is very little difficulty. The pulsating area occupies a position opposite and on a level with the second intercostal space and the third costal cartilage. On anatomical grounds, therefore, the pulsation appears to be due to the *conus arteriosus*, for at this point the aorta is too deeply placed, and the auricles too far off laterally to become prominent.

A consideration of the cycle of movements and of their relative rhythm points to the same conclusion. The aorta and auricles have very different forms of impulse wave from that which we have described, and the only other cause of the pulsation there could be is the pulmonary artery above the semilunar valves. But the impulses noted above decisively negative such a supposition, for, were the pulmonary artery the cause, there would be a distinct and lengthened rise with every systole instead of a sinking, such as we have described. On the other hand, the filling during diastole, the systolic emptying, and the transmitted shock from the blood falling upon the sigmoid valves, are exactly what we should expect to find in the upper portion of the ventricular heart.

The murmurs heard over the pulsating area are audible on account of the close proximity of the subjacent organs. In the physiological laboratory, as well as in the case of Herr Groux, it has been remarked that the first sound begins with the auricular systole. In this instance a faint murmur accompanies the contraction of the auricles, and is continued into the first sound; a murmur of soft blowing character is heard along with the first sound, and cannot be due to any cause other than the upward flow of the blood immediately beneath the end of the stethoscope; finally, a low hushing murmur is caused by the entrance of blood during diastole.

The arhythmia induced by pressing upon the tumour appears to be caused by obstruction to the free exit of the blood, which brings about the often repeated effort of the ventricle to empty itself. The inspiratory swelling seems to be due to full expan-

sion of the lungs, the right and left portions being lung tissue, while the median tumour above, seen on expiratory efforts with full lungs and closed glottis, is caused by venous stasis.

It is interesting to notice that the interference with mesial union has extended to the abdominal as well as the thoracic parietes; and we may remark that the fact of presternal fissure being present, shows that, in this instance, the union of the lateral halves from above downwards, described by Rathke, has not occurred in the normal order of succession.

CASE OF CONGENITAL AND PROGRESSIVE HYPERTROPHY OF THE RIGHT UPPER EXTREMITY. By WILLIAM OSLER, M.D., M.R.C.P., *Professor of the Institutes of Medicine in M'Gill University, Montreal.*

HYPERTROPHY of one extremity or of one side of the body must be ranked among the very rare abnormalities of development. Trelat and Monod in their memoir,[1] published in 1869, were only able to collect twelve cases, apart from instances of hypertrophied fingers and toes, which are much more common. Since that date the only other case to which I can find reference is one reported by Ewald in Virchow's *Archiv* (1872), in which the left hand was affected. Of the cases summarised by Trelat and Monod, in one it was confined to the right upper extremity, in six both upper and lower limbs of one side were affected (4 on the right, 2 on the left side), and in all the leg much more than the arm; in two the leg alone was involved; in one the right side of face, and in one the right side of head and face. With the exception of a case of Mr Adam's (*Lancet*, 1858) all of these are reported by continental writers.

I am indebted to my colleague Dr Drake for the opportunity of examining the following case, and for permission to publish the notes.

A. B., aged 8 years and 10 months, a well grown, healthy-looking girl, the eldest of a family of four; parents healthy. The mother states that while pregnant her brother met with an accident by which his hand was severely crushed, necessitating the amputation of several fingers. She did not see him until six weeks before her confinement, when the hand had healed, but the appearance of it gave her a great shock, and, of course, she attributes the deformity to this cause. Dr F. W. Campbell, the family physician at the time, informs me that the enlargement of the arm was quite noticeable at birth; but his attention was chiefly directed to the hand, which was deformed, with the fingers strongly flexed, and attempts were made to remedy this condition by the use of a straight splint. Not long after the case came

[1] *Archives Générales de Médicin*, 1869.

into Dr Drake's hands, and has been under his observation ever since, and he bears testimony to the gradual and progressive growth of the limb with the development of the child. The mother thinks that the arm is larger in proportion, and more noticeable now than in infancy.

The present condition is as follows:—

When stripped the child presents a remarkable appearance from an abnormal development of the right upper extremity, which, in contrast to the limb on the left side, looks like that of a medium-sized man. The enlargement extends to the muscles of the shoulder. Sides of face and abdomen symmetrical, legs of equal length and size. Chest is well formed, expansion good, equal on both sides; right half measures 4 centimetres more than the left. Right pectoralis major is hypertrophied, and stands out very prominently when contracted. Right shoulder is considerably larger than the left, and when she stands straight is on a higher level. The deltoid is greatly developed, the trapezius less so. Scapulæ equal in size; no marked difference in their muscles. Right clavicle is a little longer than the left (6 mm.), sterno-cleidomastoid muscles of equal size.

The following are the comparative measurements:—

Chest, just below nipple, circumference, 56 centimetres.

Chest, right half, 30 centimetres; left half, 26; difference, 4.

Upper extremity from tip of acromion to styloid process of radius, right, 42 centimetres; left, 37; difference, 5.

Clavicle, length, right, 11·5 centimetres; left, 10·9; difference, ·6.

Humerus, length, right, 24·1 centimetres; left, 21; difference 3·1.

Arm, circumference, biceps extended, right, 18·5 centimetres; left, 15·6; difference, 2·9.

Arm, circumference, biceps strongly flexed, right, 20·3 centimetres; left, 15·9; difference, 4·4.

Humerus, width across condyles measured with pair of compasses, right, 7 centimetres; left, 6; difference 1.

Fore-arm, circumference, thickest part, right, 21·2 centimetres; left, 17; difference, 4·2.

Wrist, circumference, right, 15·5 centimetres; left, 12; difference, 3·5.

Hand, circumference, right, 20·3 centimetres; left, 15·7; difference, 4·6.

Hand, across metacarpal joints, right, 9·5 centimetres; left, 7; difference, 2·5.

Middle metacarpal bone, length, right, 5 centimetres; left, 6.

Middle finger, length, right, 8 centimetres; left, 8·5.

Index finger, length, right, 7·7 centimetres; left, 7; difference, ·7.

Thumb, first joint, circumference, right, 9; left, 6·5; difference, 2·5.

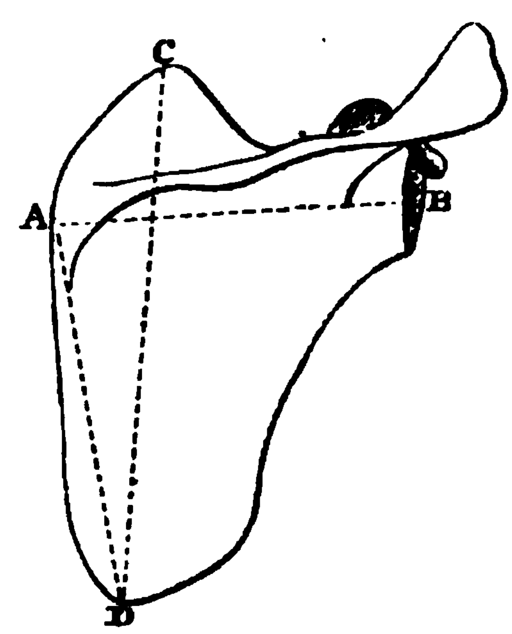
The muscles of the humerus are strongly developed, the biceps particularly so, and it stands out in bold relief when flexed, feeling also much firmer than the corresponding muscle of the other side. The fore-arm presents a very substantial muscular appearance, and affords a striking contrast to the child-like aspect of the other arm. The wrist is thick and solid; the hand square and thick, short in proportion to its size, with large and prominent knuckles. The palmar surface presents a thick pad of fat, over which the skin is loose and more creased than usual. The ball of the thumb is large, and all the muscles are strongly developed. The fingers are small in proportion, and are kept in the semiflexed position, which gives a somewhat deformed appearance to the hand. With the exception of the middle finger, they can all be fully extended, and it has a moderately free range of motion. When born the fingers were much more flexed, and the power over them has only been gradually acquired by use. The position of semi-flexion does not trouble her in the least, as she can at will extend the fingers sufficiently for all practical purposes. Skin on the limb is normal. Temperature on both sides equal. Sensibility perfect. No perceptible difference between the brachial pulses. Beat of the left radial is if anything more distinct than that of the right. Arteries are not apparently enlarged. Muscular power of hypertrophied limb is greatly increased. It could not be accurately measured with the dynamometer, as the instrument could not be properly grasped in the hand, but the difference was most marked on comparing the grip of the two hands, that of the right being very firm and powerful compared with the left. She is naturally right-handed, and uses the limb for sewing, writing, and all ordinary duties.

ON THE SCAPULAR INDEX AS A RACE CHARACTER IN MAN.

By W. H. FLOWER, LL.D., F.R.S., and J. G. GARSON, M.D., *Royal College of Surgeons of England.*

IN the *Bulletin de la Societe d'Anthropologie de Paris,* tom. i. (3rd series), 1878, page 66, M. Broca has called attention to the form of the scapula in man and a considerable series of mammals, and has, for the first time, formulated the principal differences in the shape of the bone by establishing an index or numerical expression of proportion between its chief diameters—the length and breadth. Besides this, which he calls the scapular index, he has established a second, to show the relative development of the infraspinous plate (post-scapula, *Parker*), this he calls the "indice sous-épineux," or infraspinous index.

The breadth of the bone (AB) is taken from the centre of the posterior or outer border of the glenoid fossa (B), along the base or attached border of the spine, to the point (A) where this line intersects the vertebral border. The length (CD) is the greatest distance between the posterior superior (C) and inferior (D) angles. The infraspinous length is that between A and D.



The general result of the series of measurements made by M. Broca shows that, among the mammalia, man has exceptionally low indices, both scapular and infraspinous. The anthropoid apes, he found, approach man, but between these and the other quadrumana there is a wide interval. In the bats, however, in which the function of the scapula, as a basis for the attachment of the muscles of flight, is totally different from that of animals having a quadrupedal mode of progression, the index is lower even than in man.

With regard to the different races of men, the materials at M. Broca's disposal were not sufficient to establish any very

satisfactory conclusions except in the case of Europeans and Negroes. From an examination of twenty-three skeletons of the former and twenty-four of the latter he has arrived at the following conclusions: that the scapular index in Europeans is 65·91, and the infraspinous index 87·79. In the Negroes, however, the scapular index is 68·16, and the infraspinous index 93·88. In other words, the length of the scapula compared to the breadth in the Negro is less than it is in the European. This, as far as can be judged at present, is a sign of degradation, and is certainly an approach to the form of scapula in the anthropoid apes, as can be seen from the table of measurements and indices of the scapulæ of the chimpanzee, gorilla, and orang-utan.

The necessity of a large series of observations from which to deduce an average is evident, when we examine the individual cases, as many of the Negroes have indices as low as some Europeans, and *vice versa*. The general peculiarities of the race are only developed by an extensive series. As even our largest anatomical collections are still most insufficiently supplied with skeletons, it is only by the combined contributions of various persons having access to different collections that material can be brought together to test the value of this character, and towards this end we offer the following results of measurements of scapulæ which have come under our observation, the greater number of them being in the Museum of the Royal College of Surgeons of England.

We must mention that only scapulæ of fully adult persons, in which the epiphyses were united, have been employed—a very necessary precaution in establishing an average, as the form, and consequently the indices of the scapulæ, are very different before the union of their epiphyses; secondly, the scapulæ of subjects of both sexes have been taken indiscriminately, not only because sexual difference is, as shown by Broca, comparatively little, but because, in some cases, the sex was unknown, and in others the numbers were insufficient to separate them with advantage; finally, both scapulæ of each individual have always been measured, as we find that there is often considerable variation on the two sides of the body. In several of the series, it will be observed that an odd number is

given: this arises from one of the scapulæ being either absent or in such an imperfect condition as not to afford reliable points of mensuration.

We have endeavoured to establish the mean dimensions and indices of European scapulæ from a sufficient number of cases to afford a safe basis of comparison. The 200 specimens measured are mostly from this museum or other anatomical collections in the metropolis, and are partly English and partly —perhaps in largest measure—French; there may be a few of other countries, and perhaps even of other races, accidentally included, but the number of the latter, if there are any, is not sufficient to affect the average. They have not been selected with reference to any particular object as to form, size, &c., but every scapula available has been measured until a number which seemed sufficient for the purpose was obtained.

The general result is, that of the 200 European scapulæ, the average scapular index is 65·20, while the infraspinous index is 89·40. These are the indices of the mean dimensions, which are: breadth (AB), 101·42; length (CD), 155·54; and infraspinous length (AD), 113·46. Comparing these indices with those obtained from the European skeletons in Paris, we find that the general results obtained by Broca and ourselves correspond very closely. M. Broca gives the scapular index of the Europeans as rather higher than the index we obtained, it being in his skeletons 65·91; whereas the infraspinous index obtained from our measurements is higher than his, the latter being 87·79; however, the actual difference in either case is very inconsiderable.

Although possessing a fair aggregate number of skeletons of different nations, unfortunately we have not a sufficient number of any particular race, except of Europeans, and perhaps of Andamanese, to establish satisfactorily its scapular indices. However, trusting that, by the addition of the measurements of those we possess to those in other museums, it may be possible to obtain a sufficient number for this purpose, we subjoin a table containing the number of scapulæ of each race measured, and their scapular and infraspinous indices. The measurements are all taken in millimetres, with the sliding callipers commonly used by us for similar purposes.

TABLE I.

No.	Race.	Scapular Index.	Infraspinous Index.	M. Broca's Measurements. Scapular Index.	M. Broca's Measurements. Infraspinous Index.	Remarks on M. Broca's Measurements.
1	2 Peruvian Scapulæ, .	57·8	75·1	68·02	91·74	1 skeleton.
2	6 Tasmanian do. .	60·3	81·4			
3	4 Eskimo do. .	61·6	80·5			
4	2 Samoyede do. .	62·1	89·5			
5	2 Papuan do. .	64·5	87·6			
6	2 Bornean do. .	64·8	89·8			
7	2 Lapp do. .	64·8	89·1			
8	200 European do. .	65·2	89·4	65·91	87·79	23 skeletons.
9	6 Bushman do. .	66·7	90·7	60·96	83·18	1 skeleton.
10	2 Ancient Egyptian do.	68·1	93·3			
11	12 Australian do. .	68·9	92·5			
12	21 Andaman do. .	69·8	92·7			
13	2 Tahitian do. .	70·3	95·6			
14	6 Negro do. .	71·7	100·9	68·16	93·88	25 skeletons.

From the cases in which only two scapulæ (those of a single individual) have been measured nothing can be inferred. Of those in which a large number was available, the Andamanese and the Australians, as might be expected, conform with the Negro type. M. Broca has remarked that the two skeletons of the Bushwomen at Paris are separated completely in this respect from the Negro, and enter the Caucasian type, their scapular indices being below 61 in both cases, and the infraspinous index 78·30 in the one and 83·18 in the other. He asks whether this is an individual peculiarity, or whether it will be confirmed as a race character by other observations. Of our three skeletons, the average is 66·7, the highest being 70·7, and the lowest 63·7. The average infraspinous index is 90·7, the highest being 94·0 and the lowest 87·1; so that, although the individual differences are great, the average of the three differ but little from that of Europeans in both measurements. The Tasmanians also, most unexpectedly, differ from the other black races, the average scapular index of the three individuals measured being only 60·6, the maximum 66·0, the minimum 53·7, while the average

infraspinous index is 81·4, the maximum being 90·5 (in the bone in which the scapular index was highest), and the minimum 72·1.

We have also measured the scapulæ of all the adult anthropoid apes in this Museum and in the British Museum. It will be seen that our figures (in the first columns) correspond in the main, very nearly, with those obtained by M. Broca, except in the case of the orang-utan, of which animal we have had the advantage of measuring a considerable series, giving, of course, an average more to be relied upon than the single specimen measured by M. Broca.

TABLE II.

Anthropoid Apes.	Scapular Index.	Infra-spinous Index.	M. Broca's Measurements.		
				Scapular Index.	Infra-spinous Index.
21 Chimpanzee Scapulæ,.	69·9	133·8	Of 5 skeletons	68·52	130·23
16 Gorilla do. .	72·2	132·5	10 do.	70·38	126·05
17 Orang-utan do. .	77·6	103·8	1 do.	69·27	97·46
8 Gibbon do. .	96·5	201·2	7 do.	96·97	198·56

ON THE VARIETIES OF THE ATLAS IN THE HUMAN SUBJECT, AND THE HOMOLOGIES OF ITS TRANSVERSE PROCESSES.

By WILLIAM ALLEN, M.D., *Senior Demonstrator of Anatomy, University of Glasgow.* (Plate II.)

Part I.—VARIETIES.

MY attention having been lately directed to an abnormal atlas in a subject undergoing dissection in the rooms, I have been led to make some inquiries as to the numerous variations exhibited by this bone, with a view to their classification.

These variations are not confined to any one particular part of the bone, but are found most frequently in the transverse processes, and next to them in the posterior arch, while in the anterior arch they are comparatively rare, and, as far as my observations go, the lateral masses are not subject to any striking variation except the slight differences in depth of the superior articular surfaces which exist at the different periods of life.[1]

The following description of those abnormalities is given in their order of frequency, and therefore the specimen which first attracted my notice, although interesting on account of its clinical importance, will not be referred to till after most of the others.

I. TRANSVERSE PROCESSES.—*Normal Anatomy.*—The most constant arrangement of this part is with the arterial foramen piercing its base and its two elements more intimately fused beyond the foramen than in vertebræ lower down the series. The two parts have slightly different directions; the anterior element [2] passes downwards and outwards, while the transverse element proper passes directly outwards, with, in some cases, a slightly upward inclination, and the common extremity is in the form of a rough ridge running obliquely downwards and forwards.

[1] These differences in depth are coincident with the changes of the occipital condyles, which have for their object the perfect balance of the head on the vertebral column, necessitated by the peculiar mode of growth of the skull.—Cleland "On the Variations of the Skull," *Phil. Trans.* 1870, p. 160.

[2] This part, to follow the morphological significance attached to the similarly situated part of the typical cervical vertebræ, should merit the title of "costal," but, as will be seen in Part II., its serial homology is different from what has been supposed.

The same obliquity occurs in the axis. It is a remarkable fact that this obliquity is in the reverse direction to that of the bifid extremity of the transverse processes of the typical cervical vertebræ, and that the only exception is in the case of the *vertebra prominens*, when its costal element bears evidence of being autogenously developed.

This is sufficient to lead one to suspect, what will be afterwards shown, that, in the first two vertebræ the development of the costal element differs from that in the other cervical vertebræ; and that the difference is one of increase, is to be conjectured by the comparison with the *vertebra prominens*.

Abnormal Anatomy.—The anterior element of the transverse process may be absent, leaving the arterial foramen open in front, and the artery protected externally by a large tubercle.

The transverse element proper I have never seen absent, although it may be diminished in size. The abnormalities which most frequently affect it, consist of exaggerated development. Increase of length produces bifidity (fig. 1). Increase in an upward direction may cause a bridge-like expansion of bone to stretch inwards to the external edge of the superior articulating surface, completing a foramen which looks towards the front, to give passage to the anterior division of the first cervical nerve (figs. 3 and 4). This condition is constant in a good many mammals, *e.g.*, ruminants.

In two instances coming under my notice, a strong process passes upwards to the under part of the *processus jugularis* of the occipital bone. In both cases the processes are thick and rounded. One of them (fig. 2), after passing upwards for a short distance, is then directed inwards towards the atlanto-occipital articulation, producing a deep notch by which the anterior division of the suboccipital nerve passes forwards. In the other case (fig. 5) the process passes upwards, and forms a junction with the jugular process, the junction being in the form of a round vertical pillar, having an oblique groove passing round its middle. This groove indicates the original formation of the pillar from two parts which at first articulated by opposed oblique surfaces, but became afterwards fused, as did also in this specimen the opposed normal surfaces of the atlas and occipital condyles.

This articulation between atlantal transverse process and jugular process of the occipital, is analogous to the articulations formed between the lumbar transverse processes of solipeds, in consequence of their increase in an anteroposterior direction.

Normally such a state of matters exists in the human subject at the articulations between the lateral masses of the sacrum. As a proof of the similarity, it may be mentioned that when the last lumbar vertebra has a lateral mass on one side, like a sacral vertebra, united with the sacrum, while only a transverse process exists on the other side, the junction is accompanied with elevation of the lumbar vertebra on that side, and so also in this case the junction of transverse process with jugular process of occipital is accompanied by a similar elevation, as may be seen easily when the side of junction is compared with the normal side (fig. 5).

II. Posterior Arch.—Variations of this part may take the form of either increased or deficient development. The posterior tubercle may be enlarged and form a prominent spine, either single (fig 6.) or bifid.

The laminæ may be increased in depth, but this seems in the majority of cases to be due to a rising upwards of the superior edge. Perhaps this may be connected with the presence of a separate centre of ossification known to be sometimes present in this situation. As a rare occurrence small articular facets are formed between the laminæ and the edge of the occipital bone which circumscribes the foramen magnum posteriorly.

A spicule of bone often has its origin behind the groove,[1] which gives passage to the vertebral artery and suboccipital nerve, and crossing these structures, abuts against the posterior part of the superior articulating surface.

Deficient development usually is seen as a gap between the lateral halves of the arch, but, as will be pointed out further on (IV, 3.), it is doubtful if in all cases want of ossification can be laid down as the cause of the deficiency. One-half of the

[1] The point of origin of this spicule is in the position of the oblique processes of the typical cervical vertebræ, viz., between lamina and pedicle, it is a constant structure in most mammals, and is to be looked upon as the homologue of the superior oblique process.—Cleland *On the Homologies of Axis, Atlas, and Occipital Bone*, in *Nat. Hist. Rev.*, April 1861.

posterior arch may be absent, but, as a rule, this only occurs when adhesion exists between the atlas and occipital.

I have seen one case where the arch crosses the middle line, but presents a gap posterior to the lateral mass of one side to the extent of about a fifth, leaving one to imagine that the four-fifths of the arch were ossified by growth from one side only; this conjecture is strengthened by the fact that from the point of origin behind the lateral mass the arch gets more and more attenuated till it ends in a free point behind the lateral mass of the opposite side. In the case to be mentioned in more detail further on, the posterior arch was altogether deficient. Absence of the posterior tubercle and reduction of the arch to a mere ring, are cases of minor importance occasionally met with.

III. ANTERIOR ARCH.—Normally this part has a centre of ossification appropriated to itself, and osseous growth extends from this towards the lateral mass, from which it is separated by a suture. This suture usually becomes obliterated about the sixth year (Quain's *Anatomy*), but in rare cases it may remain for a considerably longer time.[1]

When the centre for the arch fails to make its appearance, ossification then extends to the middle line from the lateral masses, and in such cases when the osseous growth is feeble, a mesial suture may remain permanently.[2]

A less important abnormality of the anterior arch is the occurrence of an enlarged anterior tubercle, which projects downwards in front of the body of the axis as is normal in many of the monkeys.

IV. VARIETIES INVOLVING MORE THAN ONE PART.—Besides the cases of abnormality which are confined to one of the parts of the atlas, there are others in which variation extends over several parts. Under this head may be mentioned, first, fusion with neighbouring bones; secondly, deficient development of both anterior and posterior arches; thirdly, deficiency of the posterior arch, with the rest of the bone somewhat altered in shape.

1. In fusion of the atlas the junction is usually with the occipital bone, the superior articular surfaces and occipital condyles being

[1] See a case mentioned and figured by Humphry, *Treatise on the Human Skeleton*, p. 131, in which a lateral suture remained up to adult life.

[2] Professor Humphry, *loc. cit.*, describes a specimen showing this peculiarity.

run into one another, but, as a rule, not to such an extent as to obliterate all traces of their original separation.

In addition to the lateral masses, the arches may also be united more or less by their edges to the corresponding margin of the foramen magnum. It has been suggested that these changes are the result of early inflammatory action, and thus it may be explained that in some cases we see adhesion of one part of the atlas coexisting with absorption of other of its parts.

Luschka[1] has described such a case, in which the lateral masses and upper edge of the anterior arch, as well as half of the posterior arch, were joined with the corresponding parts of the occipital bone, while the other half of the posterior arch was absent.

Boxhammer[2] has described another case. In it the lateral masses were completely fused with the occipital condyles; the anterior arch was perfect and free; the posterior arch was open in the middle, one of its halves being free, the other completely fused with the occipital.

Another case has been more recently described by Schiffner.[3] The atlas was so intimately fused with the occipital bone as to be with difficulty detected; also its lateral masses were so little developed and so displaced as to allow the occipital condyles to articulate with the axis directly. The axis, in its turn, was fused with the third cervical vertebra, the assimilation between their arches being so great as to give one the impression that the common spine belonged more to the third vertebra than to the second.

2. The case to which I have referred at the commencement of this communication is one in which deficiency occurred in both the fore and hinder arches. It existed in an aged female dissected in the Anatomical Rooms of this University.

Its peculiarities are as follows :—

The posterior arch is altogether deficient; a symphysis is present in the middle of the anterior arch, and admits of a considerable amount of movement; the transverse processes and

[1] *Die Anatomie des Menschlichen Halses*, 1862, § 35.

[2] *Zeitschrift für rationelle Medicin*, 3 Reihe, Band 15, "Die angebornen Synostosen an den Enden der bewerlichen Wirbelsäule."

[3] Virchow's *Archiv*, vol. lxxiv. p. 320, "Ueber die Architectur des Schädelgrundes in der norm und bei Assimilation des Atlas."

lateral masses, including the articulations, are normal. On making a dissection of the soft parts, the vertebral artery and suboccipital nerve were found in normal relation to the lateral masses, and supported by a strong bundle of ligamentous fibres, which on each side sprang from a slight tubercle behind the lateral mass. The fibres of each bundle traced backwards radiated and interlaced with vertical fibres which united the posterior margin of the foramen magnum with the arch of the axis, and might be looked on as representing the posterior atlanto-axial and atlanto-occipital ligaments directly continuous with one another. The middle part of the anterior atlanto-axial ligament is in the form of a flat band, stronger than usual, which superiorly is bifurcated and attached on each side of the symphysis.

On rotation of the head, motion takes place at the abnormal joint; partly angular, partly rotatory in character. When the occiput, atlas, and axis are placed with their mesial parts superimposed, the normal imperfect apposition of the opposed atlanto-axial articular surfaces is seen, and the anterior surfaces of the halves of the atlas are nearly in the same straight line, but when the head is rotated this straight line is broken into two, which form an angle projecting forwards.

At the same time another movement can be detected; the upper edge of the transverse process which advanced is twisted downwards and forwards, while that of the opposite transverse process is twisted downwards and backwards, these different movements being produced by the superimposed facets of either side being brought into more perfect coaptation, the joint in front allowing this to be more perfect than usual.

During the rotation of the head, and the consequent angular motion induced between the lateral halves of the arch, a slight slackening of the transverse ligament of the atlas takes place, also a slight narrowing of the transverse measurement of the atlantal part of the spinal canal; but displacement backwards of the odontoid process is prevented by an unusually strong suspensory ligament, and the narrowing of the canal compensated for by the absence of the laminæ.

It is unfortunate that the history of the subject is unknown, but it is likely that no injurious consequences resulted from the abnormal condition of the parts.

A case nearly similar to this, described by Kussmohl, and referred to by Luschka,[1] is interesting on account of the clinical history being known. An epileptic boy, aged 12, was observed to have a convulsive attack after every strong movement of the head to either side. After death the atlas was found to have a deficiency in its posterior arch, and a very mobile joint in the centre of the anterior arch. The imperfect laminæ were caused to overlap, whenever the head was rotated, a constriction of the canal being brought about; and this no doubt was the cause of the epileptic seizures, by producing pressure and irritation of the membranes of the cord.

3. A specimen (fig. 8) which I have lately met with is a good example of deficiency of the posterior arch, accompanied with a peculiar alteration in the shape of the ring of that bone. As will be seen anon, it is likely to have some obstetrical interest attached to it. The peculiarities of the specimen consist of a deficiency of the posterior arch, accompanied by an increase of the width of the spinal canal; the anterior arch is perfect, but nearly straight, and the transverse processes are depressed and thrown forwards to such an extent that their front parts lie in the same line as the anterior arch.

By pressing on the sides of the laminæ, their free ends are approximated so as to close the posterior deficiency and reduce the width of the spinal canal to its normal dimensions. By this means also the proper curve is given to the anterior arch, and the tips of the transverse processes made to assume a more natural direction. One can easily see that in this case, deficiency of osseous growth does not account for the abnormal appearance of the bone. The abnormalities seem to me to be due to some force, which had at an early period acted wedge-like between the back parts of the atlantal articular surfaces, and caused their separation, and thus altered the direction of the transverse processes, as well as produced the disjunction between the halves of the posterior arch which had up to that time been united. The effect is such as might result from the forcing of the wide back parts of the occipital condyles forwards between the anterior narrower parts of the superior articular surfaces of the atlas by strong extension of the head on the vertebral

[1] *Anatomie des Menschen.*

column in parturition, in cases of face presentation, and it is highly probable that this is the explanation. The coupling together of the anterior parts of the lateral masses by the transverse ligament, effects the preservation of the anterior arch, and at the same time makes each extremity of that arch act as a centre round which the lateral mass is rotated in the movement outwards of its back part, which is produced by the occipital condyle.

Part II.—The Homology of the Transverse Processes of the Atlas.

The anterior part of the transverse processes of the typical cervical vertebræ is now usually looked on as the homologue of a rib, its extremity being comparable with the body, its point of origin with the head, and the part directly in front of the arterial foramen with the neck of a rib. This part in the atlantal and axial transverse processes has, however, a somewhat different morphological signification from that of the typical cervical vertebræ. This is not easily made out by a comparison of the dry bones, but requires a survey of their attached soft parts as well. If the series of cervical intertransverse muscles be traced upwards towards the head it will be seen that, while the posterior intertransverse muscles pass between the tips of the posterior row of tubercles of all the cervical vertebræ, and are continued up to the head by the *rectus capitis lateralis*, the anterior muscular slips pass in the lower part of the region between the anterior tubercles; but on tracing the series upwards, the continuity with the axis is seen to be effected by a muscular slip which passes, not to the extremity of the tip of the transverse process, but to a rough mark in front of the superior articular surface. A similar slip of muscle is continued up from this roughness, passing across the front of the atlanto-axial articulation to a corresponding roughness in front of the anterior root of the atlantal transverse process, and this muscle is in its turn continued up to the head by the *rectus capitis anticus minor* muscle.

But if the series of anterior intertransverse muscles is continued upwards by the *rectus capitis anticus minor*, similarly as the posterior series is continued by the *rectus capitis lateralis*, it obviously follows in the one case, as in the other, that the portions

of bone to which these muscular slips are attached are also serially homologous.

If it be admitted that the anterior tubercles of the transverse processes of the lower cervical vertebræ are in series with the bodies of the ribs, then the body of the rib is in the atlas and axis represented by the roughness in front of the anterior root of the transverse process in each of these vertebræ; the anterior portion of the transverse process beyond this being homologous with the spicule of bone stretching in the typical cervical vertebræ between the anterior and posterior tubercles; in other words, it is the representative of a greatly elongated rib-tubercle such as exists in the Crocodilia.

Conclusive proof of the correctness of these statements is obtained by observing the mode of exit of the anterior divisions of the spinal nerves; in the lower cervical region they emerge between the anterior and posterior intertransverse muscles, and in the atlas the anterior division of the first spinal nerve escapes between *the rectus capitis lateralis* and *rectus capitis anticus minor;* further, the position of the nerve on the anterior root of the transverse process of the atlas, points out the correspondence of that part with the bridge of bone uniting the anterior and posterior tubercles of the transverse processes of the five lower cervical vertebræ.

Explanation of Plate II.

Fig. 1. Under surface of atlas with bifid transverse process.

Fig. 2. Left half of atlas seen from the front, showing a growth of bone springing from the upper surface of the transverse process and passing towards the jugular process of the occipital bone.

Fig. 3. Atlas from above, showing, *a*, spicule of bone springing from posterior arch at the upper surface of the point of junction of lamina and pedicle, and passing over the position of nerve and artery to the back part of the superior articular surface; *b*, a second spicule of bone passing from upper surface of transverse process to the outer edge of the superior articular surface, and crossing the place of exit of the anterior division of the first spinal nerve. A probe, *c*, is represented passing through the abnormal foramina.

Fig. 4. The same atlas seen from the front, showing the foramen which looks forwards and gives passage to the anterior division of the first spinal nerve.

Fig. 5. Occiput and atlas fused together, posterior view; the abnormal pillar described in the text is shown; also the atlas and base of skull are seen to be further separated on that side.

Fig. 6. Shows a large anterior and posterior tubercle.

Fig. 7. Shows an imperfect posterior arch, also a suture in the middle of the anterior arch, and on the left side a deficiency of the anterior root of the transverse process.

Fig. 8. Atlas with posterior arch open and transverse process thrown forwards, probably from the cause suggested in the text.

Fig. 9. Semi-diagrammatic view of the abnormal atlas described, in which the posterior arch is absent, and the anterior in two parts.

Figs. 10, 11, and 12 represent the left halves of a normal atlas, axis, and typical cervical vertebræ; the same letters in each, point to the homologous parts—*a* represents the position of the point in each which corresponds to the tip of a rib, *b* to the rib tubercle, *c* to the tip of the transverse process proper.

NOTE BY PROFESSOR CLELAND ON DR ALLEN'S PAPER.

The remarkable sequence of parts in the transverse processes of the atlas, axis, and succeeding cervical vertebræ demonstrated by Dr Allen, is a most important correction of the views hitherto held on the subject. To me it has an additional interest in connection with the transverse and lateral-odontoid ligaments, the sequence of which with the ligamenta conjugalia costarum of the lower animals I indicated in 1861 (*loc. cit.*). Inasmuch as the whole anterior part of the transverse process of the atlas corresponds with the tubercle of a rib, the lateral mass must be regarded as containing within it, undifferentiated from its vertebral part, a costal element corresponding with the head and neck of a developed rib. It corresponds not merely with that part of the body in other vertebræ which is developed from the arch and supports in the cervical region the joints of Luschka, in the dorsal region the facets for the heads of the ribs, but is the representative likewise of the head and neck of the developed rib, and the part of the transverse process situated in the lower cervical vertebræ in front of the arterial foramen. This is a circumstance to be taken into account when considering the large size of the lateral mass of the atlas; and it completes the correspondence of the transverse ligament with a ligamentum conjugale, inasmuch as the parts to which the transverse ligament is attached have the heads of a pair of ribs incorporated with them. The occipital extremities of the lateral odontoid

ligaments are attached to parts of the occipital bone corresponding with the attachments of the transverse ligaments, some of their fibres passing directly across, while others issue from the odontoid process of the axis, the true centrum of the atlas; and this arrangement is very similar to that of the ligamentum conjugale in ruminants, where numerous fibres spring from a body of a vertebra; only in that case they come from the centrum of the preceding vertebra, while in the case of the odontoid ligaments, they arise from the centrum of the vertebra succeeding.

ON THE INFECTION OF THE CONNECTIVE TISSUE IN SCIRRHOUS CANCERS OF THE BREAST. By C. Creighton, M.D., *Demonstrator of Anatomy in the University of Cambridge.* (With six Woodcuts.)

Sir James Paget observes: "The scirrhous or hard cancers in the breast are very far from being so uniform that they may be briefly described. I believe that they are always primary cancers; always infiltrations, and almost always seated in the first instance in some part of the mammary gland; but, when we compare their other characters in any large number of specimens, we find in them many and great diversities."[1] In the course of this paper I shall exclude from view the diversities of structure, and direct attention solely to those characters upon which the hard cancers of the breast may be generalised, and chiefly to their remarkable *infiltrating* property. And still further to define the limits of this inquiry, I shall set aside at the outset those hard tumours of the breast which have the external characters of scirrhus, but do not prove to be infiltrations. Among them are cases where the hardness depends largely on the great amount of chronic inflammatory tissue that encloses the scattered areas of glandular structure: such cases have been sometimes included in the not very logical class of *carcinoma atrophicum.* The tumours that are worthy of being called cancers are, as Sir James Paget says, "always infiltrations;" and he afterwards explains the term *infiltration* to mean that certain structures proper to cancer are *inserted among the tissues of the breast and parts adjoining.* The formation of a scirrhous cancer of the breast consists in the production of peculiar structures *in the interstices of the proper tissue of the part.* Every one will admit, without being committed to the particular form of words, that the salient feature of the disease is here indicated. In like manner, the definition of the disease by Johannes Müller brings into prominence its encroaching, invading, or supplanting character. "Those tumours may be called cancerous," he observes,

[1] *Lectures on Surgical Pathology,* 3d ed., edited by Turner, p. 606.

which supersede the natural structure of the tissues. . . . . Vessels, muscles, nerves, glands, bones—all tissues, however different—are drawn into the same cancerous degeneration."[1] The groups of tumour-cells appeared to him to spring up in the interstices of the sound tissues from some hypothetical *seminium morbi;* so little relation did they seem to have to the normal elements among which they were placed. That unaccountable appearance of cancer-cells in the midst of healthy tissues may be most clearly seen, he remarks, in *carcinoma alveolare* of the stomach, in the cell-collections that spring up at various points throughout the muscular coats. This mode of representing the structure and properties of cancer, though it is joined to a hypothesis of cell-formation that is now obsolete, has the great merit of emphasising those features of the disorder to which the chief attention must always be directed. Taking up the question of the pathology of the disease at the point where Müller left it, and still exalting the infiltrating or invading character to the same prominence, Virchow advanced the important modern doctrine that the tumour-cells, however unlike they may be to the elements among which they lie, are derived from the pre-existing normal elements by a process of transformation. He asserted that the cells of the all-pervading connective tissue were the elements out of which the tumour-cells grew; he at the same time admitted the epithelial character of the tumour-cells, and he pointed out that they chiefly affected an alveolar grouping in the midst of the fibres of the connective-tissue stroma. The connective-tissue cells were often, in health, almost hidden from

Fig. 1.—Portion of tendon in a granulating stump of the leg. × 900.

[1] *Ueber den feineren Bau der krankhaften Geschwülste,* Berlin, 1838, p. 10.

view by the fibres, but if a tract of connective tissue became the subject either of inflammation or of cancer, the cells started up into sudden prominence, assuming in the one case the more featureless form of pus-cells or of granulation-cells, and in the other case a certain more particular form of tumour-cells. The adjoining woodcut (fig. 1), showing a portion of tendon from a granulating stump, will enable me to illustrate this point briefly. In a healthy tendon prepared in the same way, few or none of the flat tendon-cells would have been visible, or at most they would have appeared as more or less interrupted linear streaks of granular substance; but in the inflamed tendon the flat cell-plates have swollen up, becoming cubical or spherical, and have asserted their presence among the tendon bundles and, in adjoining parts of the preparation, it may be observed that dense rows of granulation-cells have sprung from the same hidden source.

When the ordinarily quiescent cells of the connective tissue are roused to activity as if by some influence passing over them, the first stage brings them to a condition resembling the embryonic condition as regards plumpness and the granular character of their substance. This is the phase of which Virchow writes: "There is a stage at which one cannot decide with certainty whether, in a particular part, we have simply to do with the processes of growth, or with the development of a heteroplastic destructive formation."[1] The indifferent cells of that period assume afterwards their distinctive character, "according to the specialities of the excitation" (*je nach den Besonderheiten der Reizung*). Further than this generality Virchow does not appear, in any of his writings hitherto, to have committed himself to an explanation of the epithelial type of the cells that grow up from the connective tissue in cancers of the breast, stomach, intestine, uterus. Those organs are at least epithelial in their essential structure, and, although Virchow declares that their epithelial-like tumour elements never grow from their epithelial surface, but always from the connective tissue of the subjacent regions, the fact that the organ itself is epithelial may seem to hold out the prospect of an explanation. There are, however, says Virchow, primary cancers of bone, of lymphatic

[1] *Cellular Pathologie*, 4th edition, p. 538.

glands, of the brain substance, situations in which no epithelium occurs; he declares, therefore, for the "primary heteroplasia of all cancers;" and if we may venture to add a gloss to that text, it appears to signify that the epithelial character of its cells and their alveolar grouping are fundamental properties of cancer, just as the less pronounced features and more casual grouping of granulation and pus-cells are fundamental properties of inflammation. Writers subsequent to Virchow have not accepted this account of the heteroplasia of cancer as the most ultimate that can be reached, as I shall show in the sequel by references to the pathological text-book of Professor Rudolf Maier.

In the meantime it becomes necessary to refer briefly to another well-known view of the formation of cancerous tumours, a view that regards them as simple extensions of the pre-existing epithelium of each region. It has become customary to qualify the epithelial extension as "atypical," but the new growth is always continuous with the normal epithelium, and is derived from the latter by the ordinary process of cell-division. I cannot better explain what may be called the motive of this simple and attractive theory than in the words of Professor Billroth in a criticism of the work on epithelial cancer of the skin by Thiersch. He observes: "Remak, guided by the views on the development of the embryo which he in great part originated and intelligently carried out, certainly never believed in the origin of epidermis from connective tissue; rather than give up the doctrine that the layers of the embryo were neither formatively nor functionally capable of being mixed, he inclined to what seemed an adventurous hypothesis. Cell-division as a single and exclusive principle was maintained by Remak from the first, and regardless of consequences, alike for normal as for pathological cell-growth, and the Gordian knots that he met with he cut with the sword of his genius."[1] But unfortunately for this generous praise, and unfortunately for the summary manner of overcoming difficulties which the embryologist appears to have essayed, the pathological facts are one thing and the embryological are another. In studying the pathology of malignant tumours one is constantly brought face to face with a determining force which has no known analogy in healthy growth, and that force is *infection*. In the presence of that great factor of cancerous invasion, it is simply futile to speak of a single and exclusive principle of cell-formation, which applies alike to embryological growth and to pathological. That is merely the doctrinaire notion of an embryologist who has made an incursion into the province of pathology. The attempt on the part of a certain school of pathologists to make the embryological principle of growth the exclusive law also for tumour processes not

[1] *Archiv für Klinische Chirurgie*, vol. viii. 1866.

only leads them to ignore the element of infection in the primary seats of tumour formation, or in the immediate neighbourhood of tumours, but it necessitates a theory of the metastasis of tumours which, to say the least, fails to take account of the more conspicuous facts of the case. Secondary tumours in the viscera and in the lymphatic glands arise, according to Billroth,[1] Waldeyer,[2] and more recently Cohnheim,[3] from the transport of detached masses of epithelial cells from the primary tumour; the transported cells begin to multiply in the organs where they have been lodged, and thus secondary nodules are formed, which displace or supplant the natural tissues of the parts. According to this view, there is nothing but a change of locality, and the continuity of the epithelial growth is rigidly kept up. But there is a large body of evidence (to which I have contributed in two former papers)[4] to show that the metastasis is a true infection; that the cells of the remote organ (liver or lymphatic gland) are changed into the likeness of the primary tumour cells, and that there is, as I have elsewhere said, a consensus or co-operation among the elements of the infected part to assume the grouping and general plan of structure of the primary tumour, so that the secondary nodule is a mimicry of the primary in all particulars, even the most minute. That theory is, I believe, securely based on facts, but it is difficult to find any systematic observations in favour of the transport theory, with the exception of a recent somewhat irrelevant experiment with fragments of periosteum.[5] The theory of an actual transport of epithelium and increase of the same by multiplication has a motive behind it; it is a necessary pendant to Remak's embryological doctrine, that even in morbid processes epithelium can never grow from anything but epithelium or connective tissue from anything but connective tissue. The embryological law was probably a new revelation to pathologists in 1855; but it is now so entirely familiar that no pathological observer is likely either to ignore it or to be unduly fascinated by it.

Even for the pathology of epithelial tumours in their primary seats, or in their first beginnings in an epithelial organ, the principle of "cell-division as the single and exclusive law for normal as well as pathological growth" is a principle that goes a very little way. I have elsewhere brought together a large body of evidence[6] to show that tumours of the breast, while they start from the secreting structure, do not depend on a simple and arbitrary proliferation of epithelium, but that their origin may be traced to certain perversions of the secretory process, which the physiology of the breast enables us to follow and to estimate; that, in short, the functional factor is of the first importance in accounting for the tumours of secreting structures, and that to rest satisfied with "cell-division as the single and exclusive law" of epithelial tumour formation is simply to leave the kernel of

[1] *Loc. cit.* p. 867. [2] Virchow's *Archiv*, vols. xli. and lv.
[3] *Vorlesungen über allgemeine Pathologie*, Berlin, 1877, p. 668.
[4] *Reports of the Medical Officer of the Privy Council*, 1874 and 1876.
[5] Cohnheim and Maas in Virchow's *Archiv*, vol. lxx. p. 161.
[6] *Contributions to the Physiology and Pathology of the Breast and its Lymphatic Glands*, London, 1878.

the question untouched. While that criticism applies as regards the first beginnings of tumours in epithelial organs, the inadequacy of the proliferation doctrine is much more apparent in the case of those epithelial tumours (cancers) that have the characteristic habit of spreading or encroaching or infiltrating. In such tumours (scirrhus of the breast, for instance) it is not to continuous proliferation of epithelium that we have to look for an explanation, but to an acquired property of the morbid epithelium, namely, its power of *infecting the neighbourhood.*

The influence that causes the cells of the connective tissue to assume an epithelial form and an alveolar grouping was indicated by Virchow simply as a "special" influence. Advancing on this generality, and borrowing an expression which Virchow had applied only to the secondary or discontinuous extensions or metastases of tumours, W. Müller described the influence as a virus or an *infection,* and he compared it to the syphilitic virus or infection; it agreed with the syphilitic virus in having a special affinity for the connective tissue everywhere throughout the body.[1] But the assumption by the cells of that tissue of the epithelial form and alveolar arrangement in cases of cancer was the part of the problem that this somewhat random theory did not attempt to deal with. In the *Handbook of Pathological Anatomy* by Professor Klebs, the element of infection is introduced in a more intelligible manner, and in the text-book of Professor Rudolf Maier,[2] the doctrine that cancerous tumours extend by *the infection of the neighbourhood* is systematically expounded. In making use of the expression "infection of the neighbourhood," Professor Maier thereby indicates that the infection has a local source. The tumour is not from first to last an affair of infection, as the suggestion of W. Müller implies; but the infection emanates from a primary centre of diseased action, and, to use the language of earlier writers, it draws the neighbouring tissues into the same cancerous degeneration. In a cancerous tumour of a glandular organ or epithelial region, the epithelial new growth that makes up the whole, is referable, says Professor Maier, to two sources. A large part of it is derived from fission of the pre-existing epithelium, while the remainder is due to the productiveness of the connective-tissue cells, a

[1] *Jenaische Zeitschrift für Medicin und Naturwissensch,* vol. vi.

[2] *Lehrbuch der allgemeinen pathologischen Anatomie,* von Dr Rudolf Maier, Professor in Freiburg, Leipzig, 1871.

productiveness called into play by infection. This, says Professor Waldeyer, is "eclecticism."[1] But if any one supposes that the formation of epithelial tumour-cells from pre-existing epithelium by ordinary generation, and the formation of them from connective-tissue cells by infection, are alternative or co-ordinate modes of origin, and that to assert the co-existence of the two modes in the same tumour is to make an unscientific compromise, it is clear enough that such an one does not understand infection in the sense in which it is usually understood. That such a criticism should have been seriously made is all the more remarkable when we consider Professor Maier's very explicit statements about infection. So long as a new formation in a glandular organ is confined within the limits of the organ, so long as it retains both in structure and function the type of the normal tissue, it constitutes an adenoma; and if it be a new formation in the skin, it constitutes under like circumstances what he calls an epithelioma. But when the new growth "becomes destructive towards the surrounding tissues," when it proceeds to *infect* the neighbourhood, it becomes cancerous. The additional element in the case of cancer is clearly secondary to and not co-ordinate with the initial disturbance. Epithelial cells, and in fact the same kind of epithelial cells, are produced in two ways, but the two modes of formation do not belong to the same category; the one is a modification of healthy action, and the other is simply a mimicry of the original departure from the normal.

Inquiring more particularly into Professor Maier's doctrine of the infection of the neighbourhood, we find that the connective-tissue cells, infected to become epithelial, pass through the phase of granulation-cells. For example, in a glandular tumour, the circumference of the glandular acini, the bounding zone of connective tissue next to the epithelium, is in a state of the most active productiveness, and the young indifferent cells produced within it pass through all degrees of transformation towards the characteristic epithelium. Again, the tracts of connective tissue separating the various division or lobules of the initial disease are as if sown with young cells; it is their transformation into epithelium that accounts for the growth of the nodule at its periphery, the melting away of the septa, the increase of the cell-

[1] Virchow's *Archiv*, vol. lv. 1872, pp. 70 and 148.

infiltration, and the final destruction of the original tissue. As to the alveolar grouping of these epithelial infiltrations :—inasmuch as, in the skin or mucous membrane, groups of young cells arise out of the productiveness of the connective-tissue corpuscles, and as those heaps of cells enlarge by fission, and by the inclusion of the nearest connective-tissue cells newly infected, so the spaces and meshes of the stroma are put on the stretch and an alveolar or areolar type of structure is gradually established.

By way of general summary, Professor Maier says: At the outset of the cancerous or cancroid affection, the multiplication of the epithelial elements by fission is certainly the determining factor. But when the development has reached a certain height, and the formation in one particular direction a certain intensity, the one tissue is then in a position to work on the other; the developed cell is able to exert a sort of influence of contact on the neighbouring undeveloped cell. That infective action must be assumed to take place on a large scale, else it would be impossible to account for the persistent growth of cancers.

In treating of scirrhous cancers of the breast, I shall adopt Professor Maier's view of an infection of the neighbourhood, and I do not propose to venture on anything more ultimate about the nature of the infection than that it is "a sort of influence of contact." But for the hard tumours of the breast, something remains to be added as to the small beginnings of the disease in the original epithelium; and secondly, the relation of those initial disturbances to the subsequent infection of the neighbourhood requires to be stated in more precise terms. Thus, while Professor Maier ascribes the epithelial type of the cell produced from a connective-tissue corpuscle to an infective mimicry of the originally disordered epithelium, he refers the alveolar grouping of the cells to a mechanical cause. As the infection breaks out at one centre after another, the cells naturally group themselves in alveolar clusters, pressing aside the parallel bundles of connective tissue from the midst of which they have sprung. The alveolar grouping, which Virchow thought to be characteristic of cancer, and which is commonly associated with the notion of infiltration, is thus made to flow incidentally from the parallel arrangement of the fibro-cellular matrix tissue. The alveolar or ear grouping of the cells may, of course, be due to nothing

but mechanical necessity; but in that case the epithelial form of the cells and the alveolar grouping of them are characters of cancer that do not belong to the same category. That, then, is one of the points on which greater precision is to be desired; and another undiscussed point, intimately connected with the former, is the initial condition of the epithelium from which the infection of the neighbourhood is derived. It is with the discussion of those two points that I propose to occupy the rest of this paper, and I may here state in anticipation the conclusions that I arrive at: (1) that the initial condition of the original epithelium is in many cases that of an actual or literal infiltration into the surrounding stroma; and (2) that it is this literal and actual infiltration of epithelium that determines, through the mimicry of infection, the familiar appearance of alveolar or linear groups of epithelial cells springing up from the cells of the connective-tissue stroma at a number of independent centres.

I do not propose to consider those two propositions strictly apart, and it will in fact be most convenient to begin with some considerations about the second of them, viz., the alveolar grouping that is said to be characteristic of cancerous invasion. Among the many and great diversities which Sir J. Paget says may be observed in a collection of scirrhous tumours of the breast, we must include a certain diversity in the kind of alveolar grouping of the elements. One of the most common forms is that of solid masses of epithelium, three or four cells broad at their broadest part, tailing off into linear rows, and filling up pretty accurately the spaces in the connective tissue; sometimes these solid cords of epithelium become joined with one another by cross branches; sometimes the cells are ranged more in single file than in alveolar groups. Another not infrequent form is that in which a number of epithelial cells lie loosely among fluid in a space of the connective tissue much too wide for them; sometimes the cells show a distinct tendency to range themselves in a more or less orderly fashion round the wall of the space. Now, both of the main varieties here mentioned are alike taken to illustrate the "alveolar" type of cancerous growths. So, in the scirrhous tumours of the stomach, intestine, and rectum, similarly diverse forms are grouped under the common head of alveolar. The epithelial cells may lie in

the submucous or muscular or subserous tissue, in the form of solid anastomising cords, or as dense alveolar masses, or as loose collections occupying spaces too wide for them. Fig. 2, from a not very hard cancer of the rectum, is an example of the last mentioned kind of grouping.

Fig. 2.—From a cancer of the rectum. × 300.

But in the tumours of the stomach, intestine, and rectum, the diversity ranges so widely as to suggest other considerations. Not far removed from the kind of alveolar space containing a loose and nondescript heap of cells, is the round or alveolar space, in which the cells adhere in an orderly way round the wall. Examples of that type may be readily found among cancers of the stomach and of the rectum. Again, in cancers of the colon, the arrangement is often so orderly that it is at once recognised as a tubular-gland structure. But when the structure derived from the infection of the tissues reaches that degree of definiteness, there is no longer room for doubting that the arrangement of the cells as well as their form, in short the *ensemble* of the new growth, is the single and indivisible effect of the infective influence. Thus, if we admit that a secondary formation of tubular-gland structure, produced by infection of neighbouring tissues, is a mimicry in every particular of some primary or initial disease in the mucous membrane, there is just as little reason for limiting the scope of the infective influence in those cases where the structure is of the more nondescript alveolar kind.

The linear and alveolar groups of cells in scirrhus, which are always associated with the idea of infiltration, do not arise out of a literal infiltration or wandering of cells into the interstices of the connective-tissue stroma, but the appearance depends on the breaking out, at numerous or successive points in the infected area, of a particular kind of new formation; the preexisting connective-tissue cells transform themselves into epithelium, and group themselves in alveolar and linear collections. If, then, that alveolar and linear arrangement be not incidental to the parallel arrangement of the matrix cells, but on the other hand a result of the infection, just as the epithelial form of cell is a result of the same, it becomes necessary to search in the primary disease for the pattern of such alveolar or linear grouping, just as one goes to the initially disturbed glandular elements for the epithelial pattern of cell. I shall endeavour to show that the examination of the scirrhous breast affords evidence of such a grouping of the original epithelial cells within the limits of the gland or of the remains of the gland; there is an actual and literal infiltration of epithelium into the abundant connective tissue of the organ, leading to alveolar and linear collections of epithelial cells. The alveolar structure which one *chiefly* sees in scirrhus of the breast is that which is derived from connective-tissue cells. This is the true observation that all pathologists who follow Virchow have made; but it is not the whole truth. There is always in the background a primary diseased centre, a literal infiltration of the original epithelium, and from that focus, however small, the infection has spread to the neighbouring connective tissue, carrying mimicry of structure with it. The difficulty of the case lies in the circumstance that the primary and literal infiltration is inextricably mixed with, and in most cases completely thrown into the shade by, that process in its own likeness which it has conjured up.

I can best approach this question of actual infiltration with a description of fig. 3, and with an account of the circumstances under which the appearance occurs. The tumour from which the drawing is taken was the usual small and firm lump in the breast, in this case situated almost directly under the nipple. The subject of it was a woman, aged 52, under the care of Dr Humphry. As regards both the age of the patient and the

character of the tumour, the case was a typical case of scirrhus of the breast. As to age, I shall not delay here to adduce evidence that the scirrhous tumour of the breast is *a disease of the obsolete breast, or of the breast becoming obsolete.*[1] For the pathology of scirrhus of the breast, it is therefore of the first importance to know what the obsolete or post-climacteric condition of the breast is. Unfortunately, that is a chapter in the physiology of the breast that no writer has hitherto supplied, and there is reason to think that when it comes to be written, it will describe a process of retrogression which differs much in individuals, both in the length of time that it endures, and also in the degree of completeness to which the effacement of structure is carried. As a general statement, we may take that of Professor Orth, who tells us, in his *Compendium of Post-Mortem Diagnosis*, that we may expect to find the breast in the climacteric years atrophied to a coarse mass of almost pure fibrous tissue.[2] The periodical upfoldings and unfoldings of the breast-structure proceed, as I have elsewhere shown at considerable length,[3] in the most orderly manner. The breast, at the end of one term of suckling, lays aside its full secretory mechanism in such a manner that it can be easily resumed at the next pregnancy. Compared with the breast during lactation, the breast in the resting state may be described as much reduced in bulk, and as containing a large proportion of coarse fibrous tissue. But it returns to its full expansion on the next occasion, just as an army corps fills up the *cadres* of its regiments. After the climacteric years, the breast loses the capacity of orderly unfolding, while a gradual disorganisation of its secreting mechanism sets in. Large ducts persist longest, but even the large ducts will sometimes be found to be collapsed, and more or less denuded of their epithelium, and to have acquired a remarkable thick outer coat of granular substance, such as sometimes develops in the outer coats of arteries. Traces of the system of ducts may be found throughout the original gland area, while all traces of acini have vanished. But it would be a mistake

[1] See the statistical tables in Paget's *Lectures on Surgical Pathology*, p. 632.

[2] *Compendium der Pathologisch-Anatomischen Diagnostik*, von Dr Johannes Orth, Berlin, 1876, p. 85.

[3] *Op. cit.*, chap. i. and ii.

to suppose that this, the extreme form of obsolescence, is uniformly or even commonly found in the breasts of women just after the climacteric period. Although there is no doubt that the secreting structure is in every case finally disorganised before old age, traces of it, and it may be considerable traces of it, are discoverable five, or ten, or fifteen years after menstruation has ceased. Such traces may be seen by looking along the sides of the ducts. The belt of tissue on each side of the duct will sometimes show small clusters of involuted acini, such as I have described for the periodical resting state of the organ. In other cases the tissue near the duct contains, not indeed clusters of well-defined and entire acini, but heaps of epithelial cells in a state of disorder. To return to the case from which fig. 3 is taken, some parts of the indurated mass showed a framework of ducts, and near them clusters of acini in the contracted state; while in other parts the appearance of the epithelium was that given in the figure. Epithelial cells are ranged in parallel rows, packed, as it were, in the interstices of the gland stroma. The stroma was in many places occupied by fat-cells, and the epithelial cells were disposed among the latter in such a way that they followed their round or oval vesicular outlines. The cells are all cubical and flattened against one another, and the whole appearance suggests that they have been mechanically wedged in between the parallel fibrous bundles of the stroma. This would amount to an infiltration of epithelium in the literal sense.

Fig. 3.—From a hard cancer of the breast in a woman aged 52. × 150.

But it may be asked, How is one to distinguish this alleged actual or literal infiltration of original epithelium from the rows or clusters of epithelial cells that spring up from connective-tissue cells, and what is the evidence that there is both a primary accumulation of epithelium, and a secondary mimicry of it in the connective tissue, and not the connective-tissue product only? Fig. 3 is not unlike the figure given by Virchow in his *Cellular Pathology* (p. 539), to show the origin of the

epithelial cells of scirrhus of the breast from the connective tissue; and it may be argued that the rows of cells in fig. 3 might have originated in the connective-tissue cells of the stroma, idiopathically or without infection, just as the cells in fig. 1 have emerged from the more hidden condition of tendon-cells. In order to obtain evidence that will be unambiguous, I must refer to corresponding tumours in the bitch. Fig. 4 is drawn from a section of a hard or firm nodule in the mamma of the bitch; the double chain of glands was affected with nodular enlargements at several points, and one of the tumours was large, with evidences of malignancy. The figure shows large granular cells impacted in the interfascicular spaces. The cells in the preparation are filled with yellow pigment, and there is no doubt that they are actual epithelial cells which have travelled from the secreting structure along the spaces of the connective-tissue stroma. The same appearance variously modified occurs constantly in the preparations of this case, and I have several other specimens of mammary tumours in the bitch where the appearance is equally common and unmistakable. The infiltrated rows of cells often coalesce to form alveolar groups, and in the above-mentioned cases in the bitch, one may find as many varieties of linear and alveolar collections of epithelial cells as in the scirrhous cancers of the breast in women. I have said that the pigmented cells were undoubtedly of the nature of epithelium, and derived directly from the secreting structure of the gland. I have elsewhere

Fig. 4.—From a mammary tumour in the bitch. The cells are filled with yellow pigment. × 150.

collected evidence on that point,[1] and I shall here make use of an old woodcut to present that evidence as shortly as possible. Fig. 5 is from the normal mamma of a cat at an early period of pregnancy. On the left hand side are portions of two lobules, and on the right of the figure is a wide expanse of fat-tissue,

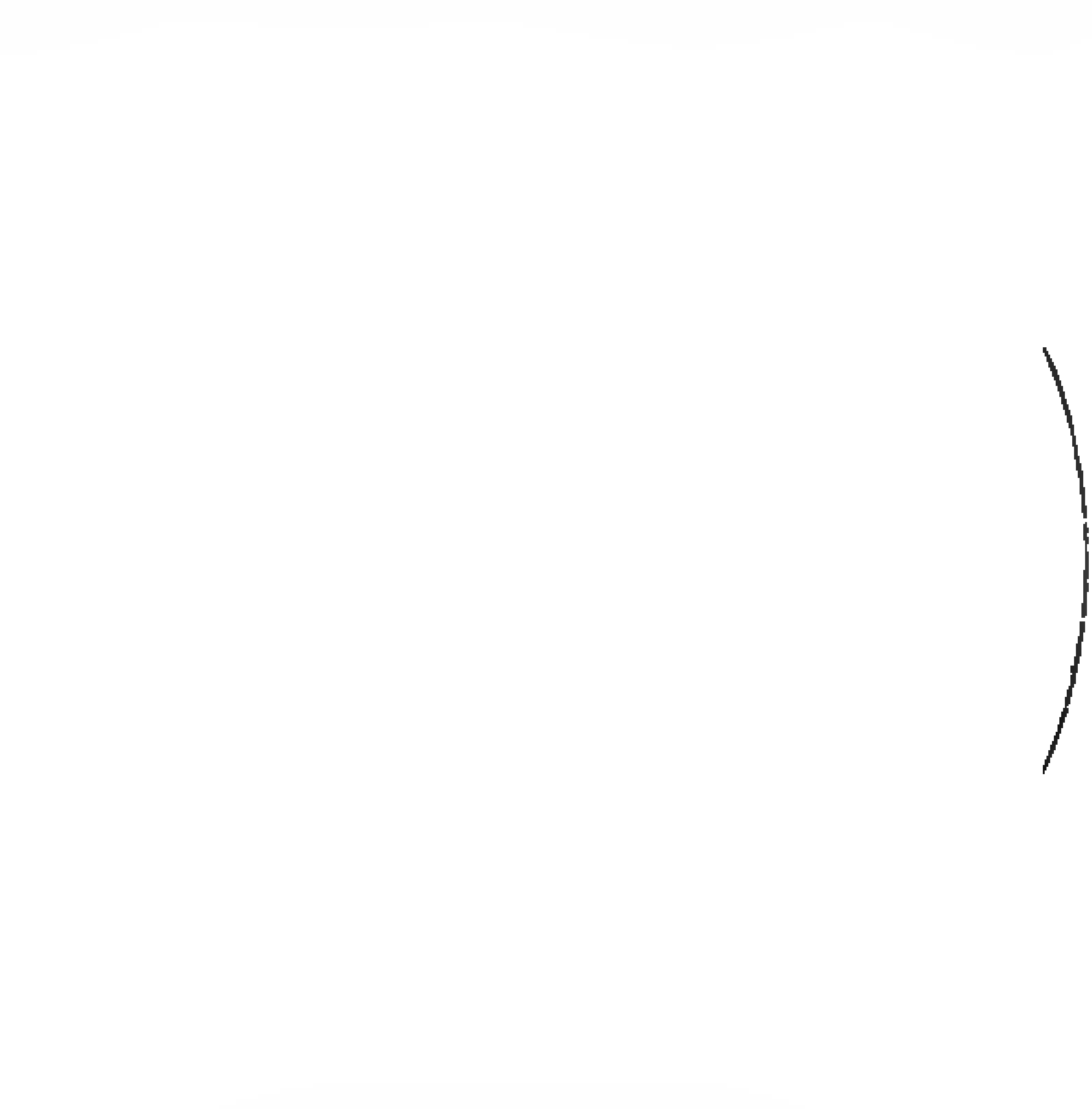


Fig. 5.—From the normal mamma of the cat: epithelial cell-products infiltrated into the surrounding tissues. × 90.

into which an enormous number of large round or oval or cubical cells have wandered. All the cells of that collection are filled with yellow pigment, and have a nucleus. The same kind of cells are found in narrow belts between the lobules; and when the source of them is looked for, it is found that they originate within the acini of the gland, and that they constitute a crude secretory product which occurs uniformly when the

[1] *Op. cit.* p. 43.

functional activity of the breast begins gradually to revive with the advance of pregnancy. Among the various points relating to this singular phenomenon of secretion, which are fully discussed in various parts of the work already quoted, I have here to direct attention only to the fact that solid products of the secretion, which have the form of epithelial cells and are plainly marked by their pigmentation, do transverse the interfascicular spaces of the stroma in the course of their removal as waste-products from the gland. Fig. 5 is a complete physiological analogy for fig. 4, and the latter appears to me therefore to explain the appearance in fig. 3, from the scirrhous breast of a woman, in the sense that I have already stated, viz., that the rows of cubical cells are the original epithelial cells of the organ, infiltrated, in the literal sense of the term, into the interstices of the connective tissue.

The occurrence of infiltrated epithelial products in the healthy breast, as shown in fig. 5, affords a sufficient explanation of the not infrequent pathological accumulation of epithelial cells in the connective tissue in mammary tumours of the bitch. In the mammary tumours of that animal, these accumulations are for the most part not the chief constituents of the tumour, but they contribute materially to its bulk. They show the same varieties of grouping as in the scirrhous tumours of the human female breast, from a linear procession of cells up to large alveolar collections. The accumulations in the mammary glands of the bitch may be explained as due to an excitation of the secreting force at an unusual time, or in an unusual degree, or under abnormal circumstances generally. In any case the tumour-like accumulations of cells are owing to a disorder of function. But that explanation does not avail for the scirrhous tumours of women, which occur almost invariably at a time when the function of the breast is obsolete, or is becoming obsolete. The infiltration in the climacteric mammary tumours may be said, however, to be incidental to the obsolescence of the breast. In some cases, if not in most cases, the tracts of surviving gland-substance along the sides of the ducts will show evidence of this. The groups of acini are in process of breaking up, and that breaking up is, at least in the cases where tumours occur, not a simple atrophy, but rather a dispersion of their epithelium. Their epithelium is found in a state of disorder, and the literal

and actual infiltration of epithelial cells into the interstices of the stroma which I have described, is one of the manifestations of the breaking up. There is evidence also of a morbid excitation among the epithelial elements within the limits of the still intact acini. But there seems to be always dispersion and infiltration, and the physiological analogy that the cases in the bitch supply, helps us in a measure to understand why such an impaction or infiltration of epithelium should take place.

The cancerous element in the disorder first shows itself when the infiltrated epithelium produces what we agree to call infection of the connective-tissue cells with which they are in contact. Those cells, as I have already remarked, following Virchow, are in a great measure hidden among the fibres, and the first step in the infective process is their emergence from concealment, as more plump and more granular cells, after the analogy of the cells in the inflamed tendon (fig. 1). The enlarged or swollen connective-tissue cells then assume the likeness of the epithelial cells whence the infection proceeded (by contact as R. Maier says, or otherwise), and many observers have persuaded themselves that they have seen all the transition stages.[1] At any-rate, one may easily observe the almost embryonic character that the hitherto quiescent stroma takes on.

Any one who examines a number of microscopic specimens of scirrhous cancers, whether of the breast, or of the pylorus, or of the rectum, cannot fail to get, over and over again, the impression that connective-tissue cells spring up in clusters in the midst of the stroma, and pass through a series of transitions towards epithelial cells. These evidences may be slight taken singly, but their cumulative weight is considerable; and it has proved sufficient for a good many observers who are perfectly able to appreciate the force of the embryological doctrine, that from the time that the three layers of the embryo are distinct, the growth of epithelium is always from pre-existing epithelium. From evidence of that kind, I have selected for drawing one particular appearance where the associated circumstances help to put the matter in a clear light. Fig. 6, from a scirrhous cancer of the breast in a female patient aged 56, under the care of Dr Humphry, shows an acinus or alveolus lined with

[1] See the figure in Virchow's *Cellular-Pathologie*, p. 533.

large cubical epithelial cells, and containing a considerable number of epithelial cells in its cavity, looking as if they had been shed from the surface. The interest centres in the connective-tissue that surrounds the alveolar space, and it is to be regretted that the engraving gives a somewhat inadequate notion of the very striking and unmistakable appearances in the preparation. In the connective tissue round the alveolus are

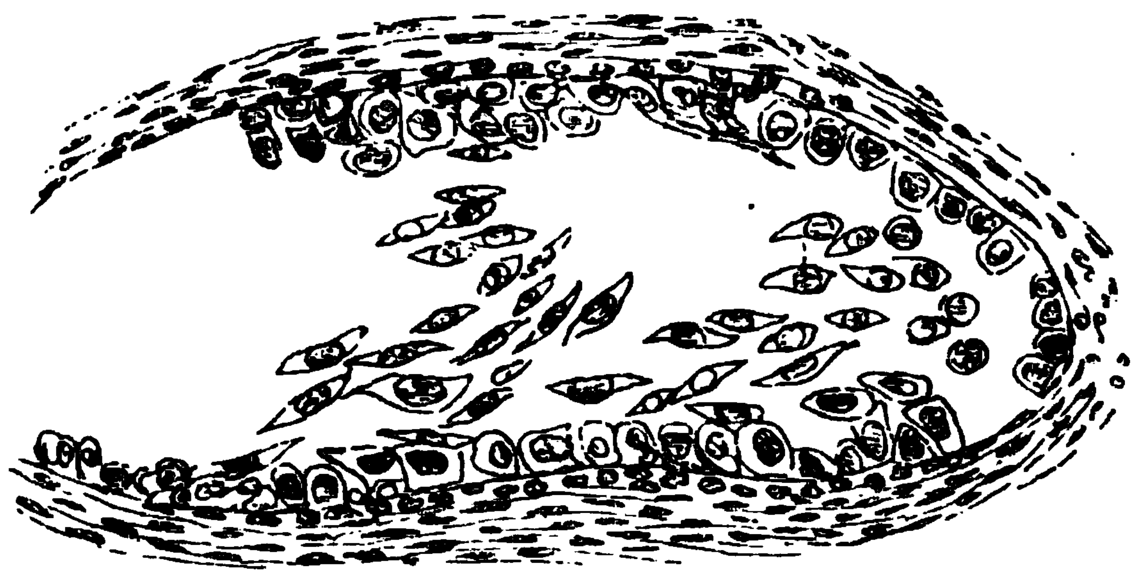


Fig. 6.—From a hard cancer of the breast in a woman aged 56. × 150.

several rows of oblong or spindle-shaped connective-tissue cells; such are the embryonic cells that one often sees in the stroma of a scirrhous tumour where infection is at work. If the row of connective-tissue cells that lies nearest to the surface epithelium be examined closely, it will be found to consist of more rounded or more cubical elements, darker in staining than the rest, and approaching to the form of epithelium. In looking at this preparation, there seems to be no reasonable doubt that the succession of cells shed into the space is derived, not solely from a process of fission in the surface row of epithelium, but from the nearest rows of stroma-cells, which in their turn assume the more cubical epithelial form, and occupy for a time the position round the wall of the alveolus. If more particular evidence is required, it may be found at the upper part of the alveolus, where a row of two or three epithelial cells are still separated from the cavity by one of the *fibres* of the stroma; the fibre is detached from the rest, but it still practically restrains the epithelial cells in the interfascicular position where they sprang up.

Under ordinary circumstances, the row of epithelial cells on the wall of the acinus would be separated from the subjacent

tissue by a more or less obvious basement membrane; whether an actual and substantial basement membrane be present or not, nothing can be clearer than the total separation of the epithelium from the tissue next to it. But here the line of demarcation of epithelium from connective tissue is broken through, and it is from the latter source that the successive generations of epithelial cells shed into the cavity are recruited.

Whether the central space in fig. 6 is one of the original acini of the gland dilated, or whether it is due itself to an outbreak of the infection in a purely connective-tissue centre, is immaterial. In either case, the line of contact of the epithelium with the connective tissue shows the process of infection at work. But the acinus-like appearance of fig. 6 recalls to mind that the structure of scirrhous cancer is not entirely that of an infiltration, or of compact masses of cells. The cells may also lie loosely in alveolar spaces, and they may have, as in this case, more or less of the regular epithelial arrangement. The acinus in question may or may not be, as I have said, an original acinus of the gland; but it is possible to identify in one region of this tumour (in one out of several sets of sections from different parts of it) a number of clusters of the original acini variously distended and altered, and the acinus of fig. 6 may be said therefore to be either an original acinus, or to be due to the mimicry of such an acinus by the elements of the infected stroma. That the infective process is capable of such mimicry may be readily seen in the scirrhous tumours of the pylorus and of the rectum, and it is a perfectly familiar fact in all the infections of the viscera and of discontinuous parts generally. That question belongs to a former part of the paper, and need not be re-opened.

The breaking down of the wall of partition between epithelial and sub-epithelial tissues, as shown in fig. 6, illustrates the real nature of the cancerous invasion in the breast. The disease has spread from the glandular tissue to the connective tissue, and no limits can now be set to its progress. No organ of the body is more of an accessory or appendage than the breast; it is simply applied to the surface of the pectoral muscle, and it can be detached without leaving a trace behind. In like manner one may remove absolutely those pre-climacteric tumours of the breast which exist strictly within the limits of the secreting

structure, and which are as definitely circumscribed and encapsuled as the fully-expanded gland of health. But no line can be drawn round a mammary tumour where infection of the stroma has set in. The disease has entered on a tissue which goes all through the body. The primary disturbance of the glandular epithelium has practically ceased to be the disease; it is the infection of the other tissue that now determines the extent and the rate of progress of the malady. As soon as a mammary tumour enters on the phase of infection, it may be said to be beyond the reach of surgery, for infection cannot be restrained by the knife. The continuous infection—infection of the neighbourhood—appears to be not different in kind from the discontinuous infection that we ordinarily know as secondary infection. The infective action which first produced epithelium from the cells of the connective-tissue stroma may show itself in the form of a crop of scirrhous nodules in the adjoining skin, just as in cancers of the intestine, it may produce a kind of miliary eruption (carcinosis) in the serous coat. In another direction, the same infective influence, howsoever conveyed, causes the pattern of the new growth to arise out of the parenchyma of the lymphatic glands or of the viscera.

The infective influence of the original epithelium on the connective-tissue cells has been compared to a kind of action of presence; but that is merely to compare one mysterious process with another, and no real explanation is conveyed by the phrase. This action of presence, or, in other words, local infection, is more apt to occur in some regions than in others. The infection of the neighbourhood, which is the essence of cancer, is most usually found in epithelial tumours of the stomach, intestine, uterus, and breast. Something may be gained by generalising the characters of the disease in these various organs, but more will be gained by treating the disease of each organ apart and by taking due account of the local circumstances of each. In the case of the breast, the condition of the organ at the time when the disease is most readily established in it deserves the closest attention. It is no longer the voluminous organ of the time of sexual maturity, with its lobules rounded off, and bounded as a whole with a more or less definite capsule. On the contrary, it is made up of a number of irregular tracts, probably having the

ducts for their central stems, extending from a sort of core under the nipple through a mass of connective tissue and fat. Looking closer at these remnants of the organ, the lobules are seen to have lost their roundness, and even the acini are found ultimately to have lost their circular contour. Atrophy does not by any means express the whole of this process of retrogression. The secreting mechanism is broken up, and the glandular cells are disbanded; it may be actually observed, in portions of the breast that would hardly be taken for diseased, that the epithelial cells, which were once contained within well-defined acini, are scattered in disorder among the connective tissue. There is at least closer contact between the individual epithelial cells and the stroma, than in the perfect state of the organ; and that circumstance may be considered to favour the mysterious action of presence which occasionally establishes itself. It may be instructive to put beside these facts observed in the obsolete breast, the conclusion of Professor Thiersch in his classical work on epithelial cancer (of the skin). "The development," he says, "of epithelial cancer rests on a disturbance of the histogenetic equilibrium between epithelium and stroma, to the disadvantage of the stroma," p. 78. *Senile changes*, he says, in the stroma of the skin cause it to offer less resistance to the encroachments of the rete mucosum, and the latter grows downwards into the stroma; thereby an epithelial cancer is formed. Professor Thiersch was led to adopt the view that the encroachment of the epidermic structure was always by way of proliferation of the pre-existing cells of the rete mucosum, and he does not admit infection as a factor in the continuous extension of the growth. But, notwithstanding this radical divergence of opinion, his phrase "disturbance of the histogenetic equilibrium between epithelium and stroma" may with advantage be pressed into the service of that doctrine of local infection which I believe to be embodied in the appearances given in fig. 6.

THE HOMOLOGY OF THE SEXUAL ORGANS ILLUSTRATED BY COMPARATIVE ANATOMY AND PATHOLOGY. By M. WATSON, M.D., *Professor of Anatomy, the Owens College, Manchester.* (PLATES III., IV.)

(Read before the Medical Society of Manchester, February 1879.)

HAVING recently been engaged with some investigations into the comparative anatomy of the mammalian generative organs, I have been impressed with the light which, as it seems to me, they throw upon the well-known conclusions of embryologists as to the fundamental similarity of plan upon which the genital organs of the two sexes are built up. I have, therefore, thought that a few remarks upon the subject might not prove altogether uninteresting to the members of this Society. Although not perhaps of any great *practical* value, the study of comparative anatomy, so far as I shall refer to it to-night, is not altogether devoid of interest to the medical practitioner, inasmuch as I hope to be able to show that we find in many of the lower animals structural arrangements which, being normal and constant in them, are only occasionally and abnormally present in the human subject. The investigation, therefore, of these lower and permanent forms is of value, inasmuch as it may throw light upon the rare and with difficulty procurable abnormalities occasionally met with in man. Further, if it be true, as stated by Serres, that "human organo-genesis is a transitory comparative anatomy, as, in its turn, comparative anatomy is a fixed and permanent state of the organo-genesis of man," we shall in the course of these investigations find structural arrangements which, being only evanescent and temporary in the human embryo, are permanently represented in one or other of the lower animal forms, and thus be enabled, so to speak, to check the observations of the embryologist, which, by reason of the minuteness of the structures he investigates and the rapidity of the changes which they undergo, are difficult of completion and not unfrequently admit of subsequent correction. As evidence of the difficulty of these researches, I may merely mention the

fact that not fewer than four distinguished embryologists—Müller, Bischoff, Coste, and Follin—arrived at erroneous conclusions with regard to the persistence and subsequent development of the primary sexual canals of the mammalian embryo, conclusions which were only corrected by the more elaborate investigations of Rathke and of Kobelt.

In attempting to give a concise demonstration of the homologous structures in the two sexes, I shall, in the first place, sketch briefly the arrangement and mode of development of the sexual organs of the human embryo, and having thereby arrived at certain conclusions, shall endeavour to show that these are further substantiated by a reference to the facts of comparative anatomy and of human pathology.

For the sake of clearness of description, we may conveniently distinguish two portions of the generative system in each sex, an *internal* and an *external*, including in the former all those parts which lie *internal to* or *above* the junction of the sexual and the urinary passages, and in the latter those which lie *external to* or *below* that point. In the *female* the internal organs thus defined include the ovary, the Fallopian tubes, uterus, and vagina; whilst the external organs comprise the vestibule, clitoris, and glands of Bartholini. In the *male* the testicles with their ducts, the seminal vesicles, and the vesicula prostatica constitute the *internal* organs; whilst the penis, scrotum, and Cowperian glands form the *external* organs of generation.

Internal Organs of Generation.

Developmental Sketch of Internal Organs in Man.

At an early period of embryonic life two glandular bodies—the Wolffian bodies, or primordial kidneys—make their appearance within the abdominal cavity. Each of these is provided with a duct—the Wolffian duct,—which, passing backward along the outer side of the corresponding Wolffian body, opens posteriorly into the sac of the allantois. At a somewhat later date two other ducts—the Müllerian—become visible on the anterior surfaces of the Wolffian bodies, with which, however, they are not physiologically connected. These ducts, likewise, when

traced backward, after coming into close proximity to the Wolffian ducts to form the so-called *genital cord*, are seen to open into the allantoic sac, whilst their anterior extremities communicate with the pleuro-peritoneal cavity. As regards the allantois, the observations of embryologists show that its lower or proximal portion undergoes changes which result in the formation of a wide expanded receptacle—the future urinary bladder—and of a narrow contracted segment which ultimately forms the commencement of the urethra in the male, and the whole length of that canal in the female. The termination of the urethra, taken in the stricter sense as signifying the passage by means of which the urine, and the urine alone is expelled, is indicated in both sexes by the junction of the urinary and sexual canals. This junction takes place in the adult male about the middle of the so-called prostatic urethra, and in the adult female at the vestibule. Beyond this point lies the uro-genital canal which is common to both urinary and sexual systems, and the development of which we shall consider along with the external organs of generation. All the parts above described are common to embryos of both sexes, so that, up to a certain time, the latter are indistinguishable from one another. From this time onward, however, changes take place which result in the differentiation of the sexual organs. In the *male*, the Wolffian ducts persist and ultimately form the vasa deferentia, the vesiculæ seminales being developed as diverticula from their posterior extremities, whilst the Müllerian ducts atrophy, with the exception of a small portion, which persists as the vesicula prostatica or male uterus. In the *female*, on the other hand, the Wolffian ducts disappear almost entirely, whilst the Müllerian ducts, previously coalesced in part of their course, remain as the vagina and uterus, their non-coalescent portions persisting as the Fallopian tubes.

From this developmental sketch it will be evident that, as in both sexes the urinary bladder and urethra down to the junction of the latter with the sexual ducts are developed in a similar manner from a similar fundamental structure—the allantois,—they are strictly homologous in both, and that, therefore, the bladder, *plus* the entire urethra of the female is homologous with the bladder, *plus* the upper portion of the prostatic urethra of

the male. In like manner, inasmuch as the Müllerian and Wolffian ducts are fundamental structures common to both sexes, those parts which are developed from each of them respectively must likewise be homologous, and therefore the vagina, uterus, and Fallopian tubes of the female must be regarded as being represented (in part at least) by the vesicula prostatica of the male; whilst the Wolffian ducts, transformed in the male into the vasa deferentia, are represented in the human female by a portion of the apparently functionless organ of Rosenmüller.

From the foregoing sketch it will be seen that in tracing the development of the sexual apparatus we start from an arrangement which is common to both sexes, these latter gradually diverging from each other through the changes which occur in the genital ducts of each. These transformations are indicated in the following table transcribed from the last edition of Quain's *Anatomy*:—

Wolffian Ducts.

Female.		Male.
Tube of the Epoophoron, .	1. Upper part, . .	Convoluted tube of Epididymis.
Ducts of Gaertner, in cow and pig, ...	2. Lower part, . .	Vas deferens and vesiculæ seminales.

Müllerian Ducts.

Fimbriated extremity of Fallopian tube, . .	1. Upper extremity,	Hydatid of Morgagni.
Fallopian tubes, ...	2. Middle part, .	Tubular prolongation of vesicula prostatica.
Vagina and uterus, . . .	3. Lower part, . .	Vesicula prostatica.

Now, such being the final destination of those parts, which, as we have seen are common to the human embryo of both sexes at an early period of development, and inasmuch as we find that in respect of other systems the various stages through which these pass in the embryos of the higher animals are, so to speak, rendered fixed and permanent in the adult condition of forms lower in the scale of being, we may, reasoning from analogy, anticipate that the same law will hold good of the generative system, and that the different stages through which the organs composing this system pass in the case of the human embryo shall be represented by permanent arrangements of the corresponding parts in the lower animals. And, as a matter of fact, we

do find that, in so far as this system is concerned, the law above enunciated holds good.

At an early period of embryonic life the digestive, the urinary, and the generative organs of the human embryo have a common opening to the exterior, and this stage remains permanent throughout life in the bird, in which we find a cloaca opening externally and receiving the products of all three systems, but never undergoing a process of differentiation into two distinct channels for the transmission of the genito-urinary and alimentary products, such as we find takes place in the higher mammals. We have seen that in the male human embryo the Müllerian ducts originally present, as in other mammals, almost entirely disappear, except in so far as they contribute to the formation of the vesicula prostatica; and we have now to inquire whether there are any male mammals in which these ducts do *not* atrophy to the same extent as in man, and so represent an intermediate stage between the normal and almost complete disappearance of these in the human male and the large size which they maintain in the human female. If such we can find, we shall thereby confirm the homologies already arrived at from the study of embryology.

Examples of Male Uterus in Animals.

Proceeding with this investigation, we find a number of such animals, and drawings of the parts in question in two of them, the beaver and the ass (figs. 1 and 2), in which they are most strongly pronounced, will be found among our illustrations. The size of the remnant of the Müllerian ducts varies much in different animals, and there does not appear to be any definite law regulating either this or the form which such remnant assumes in the adult. It is not larger in the lower mammals than in the higher, indeed, in the marsupials it is generally absent, there not being, as a rule, the slightest trace of a vesicula prostatica in the male marsupial.[1] Dr Alfred Young[2] has recently directed attention to its presence in the *Phascolarctos koala*, and this observation I have myself confirmed; but the presence of a vesicula prostatica must be regarded as quite exceptional

[1] Leuckart, *Cycl. Anat. and Phys.* art. "Vesicula Prostatica."

[2] *Journal of Anatomy and Physiology*, vol. xiii. p. 315.

among the marsupials. It is equally absent in many of the Rodentia (mouse, rat, squirrel),[1] whilst in others, as the beaver (fig. 1), it is of large size, and bifurcated at its extremity, presenting in this respect a striking similarity to the double-horned uterus of the opposite sex. Among solipeds and ruminants the vesicula prostatica is generally distinguishable, is sometimes of large size, and may even be bifurcated at its extremity, as in the ass (fig. 2) and goat. Lastly, it is reduced to a minimum in the quadrumana, in which it is not larger than in the human subject. Thus in the lowest and in the highest mammals the vesicula prostatica is small, whilst in the different members of one and the same group it may either attain to considerable dimensions or be altogether absent.

Transverse Dismemberment of Uterus and Vagina in the Male.

We have seen that in the human female the Müllerian ducts unite to form the uterus plus the vagina, the latter representing the lower portion of the coalesced ducts, the former the higher portion. The non-coalescent segments of the ducts remain as the Fallopian tubes. Originally the uterus and vagina form a continuous tube without any difference of structure at different parts, and only in the fifth or sixth month of intra-uterine life do we find that transverse dismemberment taking place which indicates the separation of the future uterus from the future vagina. In the male of the human species this transverse dismemberment seldom occurs, and therefore no argument can be drawn from the normal structure of the vesicula prostatica in him in favour of the correspondence of the latter with the vagina and uterus of the opposite sex; and, *so far as mere structure goes*, we might, in the absence of other considerations, conclude that the vesicula prostatica of the human male represents *either* the uterus *or* the vagina of the female, but not both. When, however, we turn to the lower animals, we find a very cogent argument in favour of the view that the vesicula prostatica of the male represents *both* the uterus and vagina of the opposite sex, not only inasmuch as in many of these, as we have seen, the

[1] Leuckart, *Cycl. Anat. and Phys.* art. "Vesicula Prostatica."

free extremity of the male vesicula prostatica separates into two cornua in precisely the same manner as the uterus of the opposite sex, but also from the fact that sometimes, although rarely, it presents at one point a well-defined constriction which indicates externally the position of an os uteri masculini in the interior. In such cases we have an almost exact reproduction in the male of the permanent condition of the Müllerian ducts in the female. As an example of this arrangement, a drawing of the male organs of a goat (fig. 3)—an animal in which this arrangement appears to be far from uncommon—is here reproduced.

It is to be observed that the view above advocated is not invalidated by those cases in which, as in the human subject, the vesicula prostatica presents no trace of either cornua or of os uteri masculini. It is, in the absence of the latter evidently impossible to determine how much of the structure in question ought to be regarded as uterus and how much as vagina. Morphologically, undoubtedly, its lower part represents the vagina, but where the latter ends and the uterus begins, in the absence of any anatomical or physiological distinction between its parts, it is manifestly impossible to determine. At the same time, it ought to be stated that a consideration of those exceptional cases of the human male, to which attention will hereafter be directed, in which a distinct structural severance between the parts of the vesicula prostatica does take place, tends to show that the normally minute vesicula prostatica represents the vagina alone of the opposite sex, the male uterus when present being represented by a portion of the Müllerian ducts, which, in the majority of cases, altogether atrophies and disappears.

Absence of Transverse Severance of Uterus and Vagina in the Female.

In the majority of female mammals, among which I may mention man, the quadrumana, and the greater number of the carnivora, a well-marked os uteri is present, and seems to define the limits of the uterus and vagina respectively. In some, however, this structural separation is wanting; and, if further proof in favour of the homologies above indicated were needed, it is to be found in the consideration of these cases. In this connection

it is necessary to distinguish two groups of animals—firstly, those in which a structural separation between the uterus and vagina never occurs, the coalesced portions of the ducts of Müller forming uterus (physiological), and uterus *alone;* and, secondly, those in which, although a physiological vagina is formed by the lower ends of the combined Müllerian ducts, there is no distinct line of demarcation between the former and the physiological uterus,—in other words, in which there is no distinct os uteri. The first of these groups is extremely limited, and, so far as I am aware, includes but two species, the *Hyæna crocuta* (fig. 21), and *Elephas Indicus* (fig. 5). In neither of these animals is there any vagina, the united Müllerian ducts forming a single tube without transverse dismemberment, and inasmuch as this tube is adapted to the accommodation of the young, we must regard it as representing the uterus, and the uterus alone.

It is true that Professor Miall[1] is of opinion that, in the Indian elephant there is a distinct os uteri, and consequent separation of the uterus from the vagina; but inasmuch as his drawing (fig. 5) of the female organs of this animal shows that there is no trace of cornua uteri in which, as distinguished from Fallopian tubes, the young could be accommodated, and as that portion of the united Müllerian ducts which lies above the so-called os uteri appears much too limited in extent to permit of the uterine functions being effectively performed during the period of gestation, we are inclined to regard the whole length of the coalesced Müllerian ducts as forming uterus, and uterus alone, rather than as uterus and vagina, the functions of the latter being in this animal delegated to the uro-genital canal. That Professor Miall himself entertains doubts with regard to his interpretation of these facts is evident from his remark, that "it would be interesting to know something of the gravid uterus of the elephant, and in particular to ascertain, by direct observation, in what part of the united sexual ducts the fœtus is lodged, but we have no observations before us which bear upon this point."

But, whatever may be said with regard to the Indian elephant, there can be no doubt that, in the female of *Hyæna crocuta,* the coalesced portions of the Müllerian ducts form uterus and uterus

[1] *Journal of Anat. and Phys.* vol. xiii. p. 81.

alone, the functional vagina being represented by the uro-genital canal.

Thus, just as on the one hand in the *males* of certain mammals we have, as an exceptional occurrence, a transverse severance of the vesicula prostatica into uterus and vagina, so, on the other hand, we find, as an exceptional occurrence, *females* in which what may be called the normal dismemberment between these organs never manifests itself, the Müllerian ducts uniting to form uterus, and uterus alone. In *Hyæna crocuta* and *Elephas Indicus* this exclusively uterine destination of the Müllerian ducts must be regarded as altogether exceptional, as also the fact that in both the vagina, although without doubt morphologically represented by the lower part of the uterus, is, physiologically speaking, replaced by the uro-genital canal.

As instances, however, of the second and larger group of mammals, comprising those in which the lower portion of the Müllerian ducts persists as a physiological vagina, and yet in which there is no indication of a structural separation between it and the uterus, in other words, in which no os uteri is present, I may mention the common mole (*Talpa europea*) among the Insectivora, the six-banded armadillo (*Dasypus sexcinctus*) and three-toed sloth (*Bradypus tridactylus*) among the Edentata, and the common pig (*Sus scrofa*) among the Pachyderms.[1]

I have already shown, upon embryological grounds, that the uterus of the female and the vesicula prostatica of the male are alike formed by the fusion, to a greater or less extent of the two Müllerian ducts. It remains, following out the original plan of this communication, to show that the study of comparative anatomy and of human pathology serves to substantiate the conclusions, in this respect, of the embryologist.

Coalescence of the Müllerian Ducts illustrated by Comparative Anatomy.

An examination of the adult *male* organs throughout the mammalia yields, relatively to the number of species in which these have been accurately examined, but few facts in confirmation of the essentially double nature of the male uterus, for the

[1] Owen, *Anatomy of Vertebrates.*

reason that, in the majority of male mammals, what little remains of each Müllerian duct becomes in the adult so intimately fused with its fellow as to leave almost no trace of the original independence of the two tubes. At the same time, the bifurcated condition of the vesicula prostatica in the ass, beaver, elk, badger, &c., before referred to, furnishes sufficient proof that the vesicula prostatica of the male is essentially a compound structure like the uterus of the female.

Turning, however, to the *female* organs, comparative anatomy furnishes us with abundant evidence confirmatory of embryological conclusions regarding the formation of the uterus and vagina. Among the lower animals we have examples of all grades of coalescence of the Müllerian ducts, from the almost complete separation of them through life, to their almost perfect fusion to form a single structure. Beginning with the lower groups of the mammalia, we find that among the marsupials the ducts of Müller occasionally remain distinct in their entire length throughout life, so that in these animals we have two vaginæ and two uteri, the structures of opposite sides being only connected at their openings into the uro-genital canal. Such is the arrangement in the opossum (*Didelphis*), fig. 6. In others, again, as the kangaroos, the Müllerian ducts unite together in the lower part of their course, the two vaginæ of these animals being separated by a mesial septum, which however is incomplete. The two uteri, on the other hand, are quite separate. In the biscachia (*Lagostomus*), among rodents, there is a more marked coalescence of the Müllerian ducts, inasmuch as they unite to form a single vagina, whilst the two halves of the uterus are completely separated from one another by a mesial septum which extends as far down as the upper third of the vagina. In this animal there are consequently two ora uteri. In this case there is an advance in degree of the coalescence of the Müllerian ducts over that which occurs in the kangaroos, the mesial septum being confined to the *upper third* of the single vagina. In the hares (*Leporidæ*) fig. 4, also we find a complete septum uteri, but in these it stops short at the os uteri, the vagina presenting no trace of its original duplicity. In them also the os uteri is double, the two cornua uteri opening into the single vagina by

[1] Owen, *Proceed. Zool. Soc.* 1839, p. 177.

distinct orifices. A farther stage of coalescence of the Müllerian ducts is seen in the uterus of the majority of the carnivora, as well as in that of the cow (fig. 7), mare, and other animals in which the septum separating the two cornua does not extend as far as the os uteri. In such cases we have a single corpus uteri provided with two distinct cornua. In *Bradypus didactylus*[1] the septum between the two cornua uteri has almost completely disappeared, being confined to the anterior wall of the uterus; whilst in the higher monkeys and in man it has disappeared entirely, and the two uterine horns have completely coalesced to form a single corpus uteri presenting no trace of its original composition.

Coalescence of the Müllerian Ducts illustrated by Human Pathology.

Corresponding to the forms of uterus above referred to in the lower animals we have a series which, occurring as malformations in the human female through imperfection of the normal coalescence of the Müllerian ducts, almost reproduce the former. As parallels to the arrangement met with in the opossum, in which, as we have seen, the ducts remain distinct throughout their course, we have those cases of uterus didelphys which occur occasionally in the human female (fig. 8). This abnormality appears to be constantly associated with others such as render continued existence impossible, and consequently is met with only in the child at birth or in the immature fœtus; at least, so far as I can ascertain, we have no record of its occurrence in the adult. But, whilst such cases are met with only in early life, there is another set of cases of much interest occurring in the adult female. I allude to those in which the Müllerian ducts, exhibiting their normal tendency to coalesce, unite so far as those portions which ultimately form the uterus and vagina are concerned, but uniting, retain the mesial septum which, originally separating the two canals, normally disappears. The result is a double uterus and vagina, the halves of which are closely connected together externally, but internally are shut off from one another by the mesial septum above referred to (fig. 9). These

[1] Owen, *Anat. of Vertebrates*, vol. iii. p. 690.

cases exhibit an advance in development when compared with those previously referred to. In the latter the Müllerian ducts remain as distinct structures, and are in no way united, whilst in the former they have, so to speak, obeyed the normal impulse so far as to become united externally, the lumina of the tubes, however, remaining quite distinct. Malformations of this class, occurring in the human female, closely resemble the normal arrangement of the parts above described in the kangaroo among marsupials, and the biscachia among rodents, differing however in the more complete retention of the mesial septum which, as we have seen, divides both uterus and vagina into two completely separated tubes, whilst, in both the animals mentioned, the septum vaginæ is incomplete. An exactly similar arrangement, however, to that which characterises the female organs of biscachia occurs, exceptionally, in the human female. A drawing of it will be found among the illustrations (fig. 10). Another class of cases reported by teratologists as occurring in the human subject exhibit a still greater advance in the direction indicated. In these the septum vaginæ has entirely disappeared, and indications of the original separation of the component halves of the genital organs is limited to the uterus in which a complete septum persists, but does not extend beyond the os uteri. Such cases almost reproduce the arrangement which we have seen to characterise the female organs among the Leporidæ, in which there are two distinct ora uteri communicating with altogether distinct cornua, but opening into a single vagina. Cases of this kind, occurring in the human female, appear to be somewhat uncommon, and I have been unable to find a representation of one. The case last referred to, however (fig. 10), approaches very closely to it.

Again, in figs. 11 and 12 we have, occurring as an abnormality in the human female, an arrangement similar to that met with in most of the domestic animals (cow, mare, &c.). In these the septum vaginæ has entirely disappeared, whilst the septum uteri has so far atrophied as to admit of a free communication between its two cornua through the intervention of a distinct corpus uteri which opens into the vagina by a single os. Lastly, in the normal uterus of the human female, the septum uteri has *entirely* disappeared, and a single corpus uteri, without any trace

of cornua, alone remains, and into it the Fallopian tubes enter. This arrangement is reproduced in the higher quadrumana.

Occasional occurrence of Uterus of Large Size in the Human Male.

The facts above enumerated, derived from the study of embryology and of comparative anatomy, appear to leave no doubt as to the vesicula prostatica being the homologue of the uterus. We may, however, farther inquire as to whether the study of human pathology lends any support to this view.

Now, several cases have been put on record in which, in the human male, an organ of large size, and similar in form to the uterus of the opposite sex, occupied the place of the normally diminutive vesicula prostatica. In such cases the Müllerian ducts in the male have, as it were, assumed the mode of growth and consequent form which, under ordinary circumstances, are characteristic of the female.

To examine all the cases which have been put on record would only weary the reader, and I shall therefore content myself with a reference to two of the most marked, one of which is delineated in figs. 13 and 14. The first to which I shall refer is reported by Petit,[1] and occurred in the body of a man aged twenty-two. Sir James Simpson[2] thus describes it:—"The external organs appear to have presented no deviation from the male type, except in the absence of the testicles from the scrotum, these bodies, with male vasa deferentia, vesiculæ seminales, and a prostate, were found to co-exist with female Fallopian tubes, and an uterus that was attached to the neck of the urinary bladder, and opened into the urethra between this neck and the prostate. The form of this imperfect uterus, M. Petit remarks, merited for it rather the name of a vagina than of an uterus, and it resembled more this organ in the female quadruped than in woman. From the body of the uterus, at 3 inches from its entrance into the urethra, two Fallopian tubes arose. These tubes were perforated, and were 3½ inches long; their abdominal extremities were not loose and provided with fimbriæ, but were attached to a small soft body on each side,

[1] *Hist. de l'Acad. Roy. des Sc.*, 1720, p. 38.
[2] *Cyc. of Anat.*, art. "Hermaphrodism."

occupying nearly the natural situation of the ovaries, but having the substance or structure of the testicles, and provided with an epididymis and vas deferens. The vasa deferentia were each 7½ inches long, and were attached to two long and rather slender vesiculæ seminales placed alongside of the uterus. The vesiculæ opened into the urethra by two ducts."

The second case, drawings of which will be found among our illustrations (figs. 13 and 14), is recorded by Franque,[1] and almost exactly resembles that above described. It differs, however, in the important particular that the vagina was clearly differentiated from the uterus through the development of a well-marked os uteri. The vasa deferentia, moreover, did not remain pervious to their terminations, and were for a considerable part of their course embedded in the wall of the uterus, exactly as are their homologues, the canals of Gaertner in the uterine wall of the sow.

Sir James Simpson's observations on the first of these cases are of interest from a physiological point of view. He says—"In a note appended to this case, M. Petit states that he had been consulted by a man who rendered blood by the penis regularly every month without pain or any troublesome symptom. Perhaps, adds M. Petit, this man had also a concealed uterus. We have been informed, on credible authority, of two similar cases, the one in a young unmarried man of seventeen years of age, and the other in a person who had been married for several years without his wife having had any children. In both of these cases the discharge was in very considerable quantity, and perfectly regular in its monthly occurrence. Did it consist in a periodical hæmorrhage from the urinary bladder or passages only? or was it, as M. Petit seems to suppose in this instance, of a true menstrual character, and produced by the reproductive organs of the female existing internally, and communicating with the bladder or urethra?"

Persistence of the Wolffian Ducts in Females of the Lower Animals.

Having now seen that in many and indeed in the majority of male mammals, we find a remnant of those sexual ducts—the Müllerian, which only attain their highest anatomical and physio-

[1] Scanzoni's *Beiträge zur Geburtskunde*, Band IV. p. 25.

logical development in the female—we have in the next place to inquire whether comparative anatomy throws any light on the persistence of those ducts, the Wolffian, which are only functionally perfect in the adult male. For if we be able to find cases in which in the female along with the functionally perfect Müllerian ducts, there coexist remnants, however, imperfect of the premordial Wolffian ducts, which as we have seen are originally common to both sexes, we shall thereby be enabled, so to speak, to cross check our previous observations in so far as these relate to the homologous parts in the two sexes. Now, such cases are not uncommon among the lower mammals in several species, of which, as for example, some monkeys, the mare, cow, rhinoceros, pig, and certain cetacea, we find the Wolffian ducts persisting throughout life, as the so-called canals of Gaertner (fig. 15). These canals are of very different sizes in different species. In the mare, for instance, they are small, and indeed sometimes indistinguishable; whilst in the cow, and more especially in the pig, they are of large size. They commence above, lying in close relation to the so-called organ of Rosenmüller (which it will be noticed Banks[1] has shown to be the permanent representative in the female of that structure, which in the male forms the epididymis of the testicle), and running down either in the substance of the uterine wall, or in close proximity to it between the layers of the broad ligament of the uterus, terminate by opening into the uro-genital sinus on either side of the urethral aperture. These cases serve to show that just as in certain males we have permanent remnants of truly female canals, so in certain females have we persistence of ducts which belong physiologically to the male.

Occasional occurrence of Vasa deferentia in the Human Female.

In the human female the Wolffian ducts normally disappear, with the exception of a small portion which persists along with the organ of Rosenmüller, and there is therefore in the human subject almost no representative of the canals of Gaertner of the lower animals. But just as we found that, in the perfect human male, we have occasional persistence of the Müllerian ducts, forming a well-marked uterus, so in exceptional cases we find

[1] "On the Wolffian Bodies of the Fœtus and their Remains in the Adult."

in the human female persistence of the Wolffian ducts to form vasa deferentia. Such cases, however, are extremely rare; indeed, according to Klebs,[1] only two have been put on record. In one of these reported by Realdus Columbus,[2] the female organs were well developed, but in addition to the two Fallopian tubes, two canals representing the vasa deferentia passed from the ovary down to the large clitoris. In the other, more recently reported by Fürst,[3] a double-horned uterus was present, and a single vas deferens, which lay in the external wall of the right cornu uteri, passed down as far as the lower end of the incomplete septum vaginæ, and then turned upwards to open close to the os uteri. These cases occurring in the human female, present, with regard to their comparative rarity, an interesting correspondence with what we have seen in the lower animals, in which, although the uterus is all but constantly represented in the male, the canals of Gaertner are by no means so frequently met with in the other sex.

EXTERNAL ORGANS OF GENERATION.

Developmental Sketch of External Organs in Man.

We have already traced the development of the genital canals as far as the junction of these with the urinary tract, and in order to make plain the observations which follow, it is necessary now to follow out the developmental changes which lead up to the formation of the external organs of generation, understanding by these all the parts of the urino-genital apparatus which are situated below or external to the point indicated.

At an early period in the history of the human embryo, the sac of the allantois, which as we have seen receives the genital ducts, communicates with the lower end of the alimentary canal, and both communicate with the exterior by means of a single channel,—the cloaca. This arrangement is persistent throughout life in the members of the class Aves. At a later date the cloaca, through the growth of a transverse partition, becomes separated into two parts,—an anterior, the so-called genital fissure, which

[1] Handbuch, *Der pathologischen Anatomie*, Seite 744.

[2] *De re Anatomica*, 1559.

[3] *Bildungshemmungen des Utero-vaginal-Kanals*, 1868, Seite 71.

forms the outlet of the genito-urinary apparatus, and a posterior, forming the outlet of the alimentary canal. About the same time a projection buds forth from the anterior extremity of the genital fissure, and forms the rudimentary penis or clitoris according to sex, the margins of the fissure simultaneously closing in toward the middle line. From this time forward the external organs of the two sexes previously alike begin to differentiate. In the female the margins of the genital fissure (sexual folds) never coalesce, but form the labia majora, whilst those of the male unite in the middle line to form the scrotum. In a similar manner the genital member of the female remains in an undeveloped condition as the clitoris, its lower or grooved surface remaining permanently open, by reason of the non-coalesence of the margins, which remain distinct as the labia minora and vaginal bulbs; in the male, on the other hand, the genital member enlarges to form the penis, the margins of its inferior grooved surface uniting in the middle line to form the single corpus spongiosum urethræ. In connection with the anterior and now distinct compartment of the cloaca or uro-genital sinus, and close to the junction of the latter with the base of the genital member, two glands are developed in each sex. These are the glands of Bartholini in the female, and those of Cowper in the male. Opening as these glands do close to the base of the genital member, they form landmarks of first-rate importance in the determination of homologous parts of the uro-genital sinus which differs widely in appearance in the two sexes.

From this outline it will be observed, that that portion of the male uro-genital canal which intervenes between the point of entrance of the Wolffian ducts and the Cowperian glands must be homologous with the portion which in the female intervenes between the entrance of the Müllerian ducts and the glands of Bartholini. In other words, the short and wide vestibule of the human female must be homologous with the elongated and narrow lower half of the prostatic, *plus* the membranous urethra of the male. Similarly the genital members of the two sexes are strictly homologous, differing only in size, and inasmuch as the margins of the lower or grooved surface remain apart in the female to form the vaginal bulbs (fig. 16), whilst in the male they coalesce in the middle line, and complete the spongy portion of

the urethra. The spongy portion of the urethra of the human male has therefore no representative in the human female. Finally, the labia majora are evidently homologous with the two halves of the scrotum.

The following table will make these homologies plain:—

Female.	*Sinus uro-genitalis.*	Male.
Female urethra,................	Upper part of urinary pedicle,.............	Upper portion of prostatic urethra.
Vestibule,........................	Lower part,...........	Lower part of prostatic and membranous urethra.
Glands of Bartholini,.........	Blastema,.............	Glands of Cowper.
Crura and corpus clitoridis,	Corpora cavernosa,...	Crura and corpus penis.
Glans clitoridis and vaginal bulbs,.................	Corpora spongiosa,...	Glans penis and corpus spongiosum urethræ.
Labia majora, ...	Genital ridges,........	Scrotum and raphé.

Now, just as we have seen that the conclusions arrived at by embryologists, with regard to the homologies of the internal genital organs of the two sexes, are borne out by the study of comparative anatomy and of pathology, so we shall see that the same observation may be made respecting the external organs of generation.

Comparative Anatomy of the External Male Organs.

Embryological investigation has shown us that the non-coalescent vaginal bulbs of the human female are represented by the corpus spongiosum of the human male. As farther illustrating the correctness of this view, I may adduce the cases of some few male mammals, in which the corpus spongiosum urethræ exhibits a tendency to retain its original condition; in other words, to remain as two distinct and separate halves for a greater or less part of its extent, in the same way as the homologous vaginal bulbs of the other sex persist as distinct structures. Examples of this arrangement are not uncommon among the marsupials. In some of these the corpus spongiosum splits posteriorly into two parts, thus giving rise to a double urethral bulb, whilst anteriorly it also separates into two portions, producing bifidity of the glans penis. No more powerful argument could be adduced in support of the accuracy of Kobelt's[1] views regarding the homology of the corpus spongiosum with the vaginal bulbs. The arrangement just described is met with in

[1] *Wollust-organe.*

the multiparous marsupials, such as the koala (fig. 17), opossums, and phalangers; whilst in the uniparous genera, such as the kangaroo, the corpus spongiosum exhibits a closer approach to the ordinary arrangement, the glans penis being single, whilst the bulb of the urethra remains double, as in the members of the multiparous section of these animals.

Homologies of the External Genital Organs shown by Abnormal Arrangements in the Human Male.

In the human subject the similarity in structural plan upon which the genital member of the two sexes is built up, is beautifully shown by certain cases of hypospadias, in which the two halves of the corpus spongiosum never unite in the middle line, thus giving rise to an appearance of the male sexual organs so closely simulating that of the female parts, that many cases of hermaphroditism have been described, which must now be removed from that category, seeing that they are simply examples of malformation of the male genital member, and present no trace of the co-existence of the latter with true female organs. Still more remarkable proof, however, of this fundamental community of structural plan in the two sexes, is derived from the consideration of those cases of so-called transverse hermaphroditism occurring in the human being, in which the external organs are arranged exactly as in the normal female, whilst the internal organs are as distinctly those of the other sex. Cases of this kind are far from common, but several have been put on record. The case of Maria Arsano (fig. 18) is one of the most perfect. In him (her ?) the external organs were those of the perfect female, the labia, clitoris, os vaginæ, and vulva all being normal. The vagina was only two inches in length, and ended in a blind extremity or cul-de-sac. There was no trace of uterus, broad ligaments, or Fallopian tubes. "The internal organs of reproduction were, on the other hand, completely male. The two testicles were situated in the region of the pubis, and were scarcely clear of the inguinal rings. They were of the usual ovoid figure, and natural in size. They had internally the structure of the tubuli seminiferi, but it was not well developed. The epididymes of the testes were also of the usual verniform figure, and the corresponding vasa deferentia coursed towards their vesiculæ

seminales, and terminated in an attenuated membranous expansion without any external aperture or ducti ejaculatorii. The vesiculæ seminales were placed between the urinary bladder and rectum; they were smaller and more shrunk than in the adult male, though certainly they preserved their naturally oblong form. The internal hollow or tubular structure was indistinct. The prostate gland was not present."[1] Cases such as that just described, which the possession of the *essential* organs of generation prove to be males, demonstrate conclusively that, morphologically speaking, the two halves of the corpus spongiosum urethræ and the vaginal bulbs are convertible terms. They show, moreover, that the narrow, elongated uro-genital canal of the male may be occasionally transformed into the characteristic vestibule of the female.

Comparative Anatomy of the External Female Organs.

We have seen that, founding upon embryological observations, the vestibule of the human female must be regarded as homologous with the membranous and in part with the prostatic portions of the male urethra; and that in some few instances the male uro-genital canal becomes so modified in form as to be indistinguishable from that of the other sex. Reversing the process, I shall now adduce some instances in which comparative anatomy shows that the for the most part short and wide uro-genital canal of the female becomes modified so as to present an approach to what may be called the normally elongated form of the latter in the male mammal. In this comparison, the points of entrance of the Wolffian and Cowperian ducts into the uro-genital sinus of the one, and of the Müllerian and Bartholinian ducts into that of the other sex, serve to guide us as to the corresponding segment of the canal in each. In the human female the uro-genital canal (vestibule) does not measure more than one inch in depth, whilst the length of the vagina is about six inches. In the females of several mammals, however, the uro-genital canal is proportionally much longer than in the human female, and presents an approach to the tubular form of the corresponding structure of the other sex. In the cow and giraffe it is elongated to one-fourth the

[1] Simpson, *Cyc. of Anat.* art. "Hermaphrodism."

the length of the vagina, in the lemurs to one-third the length of that tube, whilst in the platyrrhine group of monkeys the length of the uro-genital canal equals that of the vagina.[1] In the higher or catarrhine monkeys, on the contrary, the canal is always shorter than the vagina, indicating in this respect an approach to the relative proportions of these parts in the human female.

Passing now to the modifications undergone by that portion of the female uro-genital canal which lies beyond the points of entrance of the ducts of Bartholini, we find that whereas in the human female that canal is not at all prolonged forward in relation to the clitoris, in several of the lower mammals, on the other hand, a certain relation does obtain between the clitoris and the uro-genital canal, in whole or in part. Such cases exhibit a tendency on the part of the female organs to approximate to the usual arrangement of those of the male. The relation in question is closer in some mammals than in others. In some, for instance the Tupaia[1] among the insectivores, and the Capybara[1] among the rodents, the clitoris is of considerable size, and is grooved along its under surface to accommodate the upper wall of the urethra, which manifests, so to speak, a *tendency* to open at the point of the clitoris much as it does in the penis of the other sex. In others again, among which I may mention Arvicola, Lagostomus, and Bathyergus[1] among rodents, in the common mole among the insectivores, and in certain lemurs (Stenops),[2] fig. 19, the groove on the under surface of the elongated clitoris is converted by the coalescence of its margins (much as takes place in the male embryo), into a canal, and the *urethra* is thereby prolonged forward to the extremity of the clitoris. In these instances, however, only a portion of the uro-genital canal, namely the urethra (for, morphologically speaking, so much of the female urethra as lies in relation with the clitoris must be regarded as forming a portion of the uro-genital canal), is contained within the clitoris. In one at least of the lower animals, however, the female spotted hyæna (*Hyæna crocuta*), fig. 21, the entire uro-genital canal beyond the entrance to the ducts of Bartholini is prolonged forward to the extremity of the clitoris, and terminates in a manner precisely similar to that of the uro-genital canal

[1] Owen, *Anat. of Vertebrates.*
[2] *Cyc. of Anat.* art. "Quadrumana."

(urethra) of the male. The close resemblance which this arrangement of the female uro-genital canal bears to the spongy portion of the male urethra, will be evident from a reference to the accompanying drawings of the corresponding parts in the two sexes (figs. 20 and 21).

Parallel Arrangements in the Human Female.

As parallels to these remarkable arrangements in the females of some of the lower mammals, I may adduce certain exceptional cases in which, in the human female, the uro-genital canal presents modifications in form which indicates an approach to that which is usually characteristic of the male. In certain cases in which in the human female the clitoris is abnormally elongated, notably in one contained in the Museum of the Liverpool School of Medicine,[1] that organ presents a well-marked groove on its under surface, extending forward from the orifice of the urethra, and forming, as it were, the roof of an incomplete uro-genital canal exactly as in the Capybara. In another case, reported by Arnaud,[2] in which the clitoris measured 2 inches 9 lines in length, the urethra perforated that organ for a short distance posteriorly, thus indicating a tendency to that more complete separation of the urethra from the uro-genital canal by inclusion of the former within the clitoris, which we have seen to be the normal arrangement in certain species of lemurs. A still more complete, although not perfect parallel to the complete tunnelling of the clitoris by the urethra in the lemurs in the human subject is recognisable in the well-known case of Marie Lefort.[3] In her the clitoris was 27 centimetres in length. "The glans was imperforate, and invested by a mobile prepuce. The body of the clitoris was furnished inferiorly with an imperfect canal, which was pierced along its under surface and middle line by five small holes capable of admitting a small stylet, and one or more similar apertures seemed to exist in it after it reached backwards within the vagina."[4] Through this

[1] For an account of this case see *Liverpool and Manchester Surg. Reports.*

[2] *Dissertation sur les Hermaphrodites*, p. 265, plate x.

[3] Beclard, *Bulletins de la Faculté*, 1815, p. 273.

[4] Simpson, *Cyc. of Anat.*, art. "Hermaphroditism."

canal the urine was in part passed. The more complete perforation of the clitoris in this case by the urethra exhibits a closer resemblance to the normal lemurine arrangement above described than any of the others before mentioned. A parallel even to the unique arrangement above described in *Hyæna crocuta* is also met with in the human female, but to this I shall refer in the paragraph devoted to the consideration of the genital organs of that animal.

Comparative Anatomy of the Clitoris.

The clitoris in the majority of the lower animals is relatively much larger than in the human female. In some, indeed, among which I may mention certain quadrumana, and more especially the lemurs of the genus Stenops and the spider monkeys (Ateles) it attains altogether disproportionate dimensions. In the former, as we have seen, the urethra tunnels the clitoris; whilst in the latter the clitoris actually equals in size the penis of the male, and is deeply grooved along its under surface, the margins of the groove being so closely in contact as almost to form a canal. The vagina and urethra open at its base. The component parts of the clitoris in these as in other mammals are the two corpora cavernosa, which in the species referred to accurately correspond, both in size and form, to the homologous structures in the opposite sex, and thus afford an additional argument in favour of the fundamental correspondence between the penis and clitoris. An additional argument in favour of the correspondence is furnished by those animals, such as the common seal (*Phoca vitulina*), in which a distinct ossification is developed in the corresponding portion of the genital member of each sex.

Parallel Arrangements in the Human Female.

Cases in which the clitoris of the human female equals in size that of the male organ are so numerous that I need not particularise them. Indeed, an elongated and pendulous clitoris appears to be far from an abnormal arrangement among the women belonging to certain African tribes. Even in the European female cases are on record in which the clitoris has attained the extraordinary length of 7 inches.

Female Organs of Hyæna crocuta.

Striking as are these different modifications, alike in man and in the lower mammals, in the form of the genital passages of the two sexes, as indicating the fundamental similarity in plan upon which these organs are built up, there is yet one animal, the spotted hyæna (*H. crocuta*), in which the resemblance between the male and female organs is even greater than in any of the cases above referred to. So closely, indeed, do the external female organs of this animal resemble those of the male that the difficulty of distinguishing between the sexes has given rise to the ascription of hermaphroditism to the species from the days of Aristotle[1] to the present time. The organs of both sexes I have described elsewhere[2] at length, and shall now only refer to their most salient points. In the male, fig. 20, the internal organs, consisting of the testicles and vasa differentia, are arranged much as usual, the latter opening into the urethra close to the vesicula prostatica. From this point the uro-genital canal (urethra) is prolonged forward to the extremity of the penis in the usual manner. It is divisible into two portions, an intra-pelvic or membranous and an extra-pelvic or spongy portion, the point of junction of these parts being indicated by the entrance of the ducts of two large Cowperian glands. The penis, as in other mammals, is composed of two corpora cavernosa and a single corpus spongiosum. The scrotum resembles that of the true cats, being non-pendulous, and situated immediately below the anal aperture.

Passing now to the examination of the female organs of *Hyæna crocuta*, fig. 21, we find that they present a similarity to those of the male, which, viewed as a normal arrangement, appears to be altogether unique among mammals. The *internal* genital canals as above defined consist of the Fallopian tubes and uterus. The former present no deviation from what may be termed the normal mammalian arrangement. The latter, on the contrary, differs essentially from this, inasmuch as the os uteri, instead of opening into a separate vagina, communicates directly with the uro-genital canal. The vagina is therefore entirely wanting

[1] *Historia Animalium*, vi. 32.
[2] *Proc. Zool Soc.*, 1877 and 1878.

in this animal, the Mullerian ducts by their junction forming uterus and uterus alone. The *external* female genital organs likewise differ materially from the mammalian type, inasmuch as they present an almost exact counterpart to those of the male. As in the latter, the uro-genital canal of the female is elongated and tubular in form, and is divisible into two portions, an intra-pelvic and an extra-pelvic. Into the commencement of the intra-pelvic segment of the uro-genital canal of the male there opens a minute vesicula prostatica which, inasmuch as the vagina is totally absent in the female, must be regarded as homologous with the uterus, and with the uterus alone, of the latter; in a similar manner the uterus of the female opens into the uro-genital canal of that sex. As in the *male* the junction of the intra- and extra-pelvic portions of the urethra is indicated by the entrance of the ducts of two Cowperian glands, so in the *female* is it indicated by the entrance of the ducts of Bartholinian glands of the same size and form as the homologous structures in the male. As in the *male* the urethra passes forward to terminate at the extremity of the penis, so in the *female* the uro-genital canal, in the absence of a vulva, passes forward to open at the extremity of the clitoris. As in the *male* there is an elongated pendulous penis provided with a movable prepuce, so in the *female* there is a clitoris of the same size and form, provided in a similar manner with a well-developed and movable prepuce. As in the *male* there is a well-marked scrotum, so a similar structure occupying a similar position is found in the *female*. The erectile organ is of the same size, and constructed upon the same plan in both sexes, the only difference being that in the female the uro-genital canal is not surrounded by the erectile tissue of the corpus spongiosum as is the case in the male, this difference being due to the fact that in the latter the essentially bi-lateral spongy bodies have coalesced in the middle line, whilst in the female they remain distinct throughout life, and do not surround the sexual canal. In the *female*, moreover, and associated with this arrangement, there is a complete absence of the elevator urethræ and bulbo cavernosi muscles, both of which are well developed in the male.

Extraordinary and aberrant from what must be regarded as the typical arrangement of the female mammalian organs as that of

Hyæna crocuta undoubtedly is, I am nevertheless able to adduce certain cases which, occurring as abnormalities in the human female, almost exactly reproduce it. Such cases, as may be readily imagined, are extremely rare, and so far as I can ascertain only three such have been put on record. One of these,[1] occurring in a child at birth, was combined with other malformations of such a nature as to lead to some dubiety as to the significance of the parts affected; whilst in another,[2] occurring in the body of an adult aged 45, in addition to the essentially female internal organs, there were superadded the lower ends of the male vasa differentia, together with rudimentary seminal vesicles. I shall, therefore, confine my observations to the third case, in which, as along with purely female internal organs there co-existed external organs as characteristically those of the male, we find the most perfect parallel to the arrangement above described in the female *Hyæna crocuta.*

The case, fig. 22, occurred in the body of an individual named Valmont,[3] who died in Paris at the age of 36. He had been married as a male. The *internal* organs consisted of two Fallopian tubes arranged as usual, of a uterus resembling much that of the ordinary female, and of a vagina which opened into the membranous (?) part of the urethra. The *external* organs consisted of an elongated uro-genital canal, which extended from the junction of the vagina with the urethra to the extremity of the penis, exactly as in the normal male, its intra-pelvic portion being provided with prostate and Cowperian glands. The extra-pelvic or spongy portion exactly resembled the male urethra, inasmuch as it passed through a normally formed penis composed of corpora cavernosa and corpus spongiosum, and provided with all the muscles usually found in the male perineum. The penis was of medium size, and furnished with a movable prepuce. There was no trace of a vulva. A well-developed scrotum was likewise present. A comparison of fig. 21 with fig. 22 will show at once how closely the parts of this human female reproduce those of the female hyæna. The points of difference between them are few and unimportant. They consist

[1] Eschricht, *Müller's Archiv für Anatomie*, 1836.

[2] *Il Morgagni*, 1865, p. 151.

[3] See *Journal universel et hebdomadaire de Médécine*, 1833, p. 467.

in—first, the presence of a prostate gland in the woman which is absent in the hyæna; secondly, in the presence in the former of a distinct os uteri and consequent differentiation of the two portions of the Mullerian ducts which form respectively uterus and vagina; and, lastly, in the complete coalescence of the halves of the corpus spongiosum and concomitant development of the bulbo-cavernosi muscle in the body of Valmont, whereas in the female hyæna the halves of the corpus spongiosum remain separate, and the bulbo-cavernosi muscles are not developed.

We have now traced the development of the generative system in man from the time when its component parts were exactly alike in the two sexes, and when, consequently, the latter could not be distinguished from one another to that in which these organs assume the characters which are usually regarded as distinctive of each. We have, moreover, seen that, in some instances, these distinctive sexual features are never developed, so far as the genital passages are concerned, and this to such an extent that, in certain individuals (*e.g.*, Marie Arsanno, fig. 18), we find associated with *internal* genital passages essentially male in character *external* passages which are as characteristically those of the female. We have seen that the converse also holds good, and that, as in the case of Valmont, fig. 22, along with essentially female *internal* organs, there may co-exist external organs of the type usually regarded as distinctive of the male. Further, we have seen that these abnormalities in the human subject are, so to speak, reproduced as normal arrangements in the case of certain of the lower mammals, in which we find that the male presents features which assimilate it to the female (*e.g.* koala, external organs; beaver, internal organs), whilst, on the other hand, there are certain females (*e.g.* cow, internal organs; hyæna, external organs) which present features in the arrangement of the genital organs which indicate an approach to those of the males of the same species. Taking these facts into consideration, the question arises, What value is to be placed upon the arrangement of the genital passages as a criterion of sex? The answer must be, that the genital passages *per se* afford no such criterion. That this conclusion is not devoid of practical interest is well shown by the views of two distinguished French

writers, MM. Bouillaud and Manec,[1] regarding the sex of the woman Valmont above referred to. With reference to this case, M. Manec says—"If we take a general view of the arrangements which have been pointed out, we see that the malformation in question does not deserve the name of hermaphrodite, seeing that there are only present the organs of a single sex, those of the female. The only difference existing between this individual and a well-formed female is to be found in the fact that the vagina, instead of terminating on the exterior by means of a wide and independent aperture placed between the anus and the meatus urinarius, contracts to a line in diameter and opens into the urethra. The absence of a vulva, and the presence of a well-formed penis, is explained by the excessive development of the labia minora and of the clitoris, the former by their junction having caused the disappearance of the vagina and formed the raphé, whilst the clitoris, developed beyond measure, has acquired all the characters of the penis which, in the normal condition, it only imperfectly represents. It is also in virtue of excess of development that the urethra has acquired the characters of that of the male. Thus, so far there is not a single new organ present in this woman; all those which are present and which might suggest doubts as to the sex are present in a rudimentary condition in the well-formed female. There is therefore only an excess in size of the external genitals, and consequent suppression of the vulva, together with union of the urethra and vagina. The prostate, however, which does not exist in the female, is here, where it is well formed, and embraces as in man the neck of the bladder and the beginning of the urethra. If, then, this organ were essential to the male genitals its presence would embarrass us, and compel us to recognise in this case a commencement of hermaphroditism. . . . . The prostate in the male is only an accessory organ secreting a fluid which by its mixture with the sperm facilitates the progress of the latter within the urethra, and its forcible projection beyond that canal. The mixture of the prostatic fluid is not a necessity to the accomplishment of fecundation, seeing that, in several species of mammals, this takes place notwithstanding the absence of the prostate. . . . . This fact proves that the prostate cannot be considered as

[1] *Journal universel et hebdomadaire de Medécine*, 1833, pp. 472 and 489.

an essential sexual characteristic, and consequently its presence in a female cannot contribute anything toward giving her the slightest resemblance to the opposite sex. . . . . This case confirms de Blainville's ideas of the analogy existing between the organs of the two sexes, and realises the supposition made about fifteen years ago by that learned naturalist, that the only essential difference between the two sexes, consisting in the independence of the genital canal of the female, it would suffice to make of the latter an apparent male to unite the urethra with the vagina."

To this M. Bouillaud replies—"M. Manec seems disposed to place Valmont among the women. He, therefore, does not fear to place himself in opposition to the civil law, to the church, and even to Valmont himself, who had the courage and feeling of manhood to marry a woman. I confess at the same time that there is no law obliging us to believe in the infallibility of the civil law, or even of the church, so far as monstrosities are concerned, and, if with regard to them, the facts being put aside, I had to choose between the opinions of a mayor, a priest, and of M. Manec, I would not long hesitate. But it appears to me very difficult, conforming to the dictates of a sound anatomy, to find in Valmont all the elements of a woman and the true and pure elements of a woman alone. What a woman! Bon Dieu! An individual who has not a vulva, who has only the rudiment of a vagina following upon the vesical extremity of the urethra, who possess a penis, a scrotum, a prostate, and Cowperian glands all well-formed! What man would desire to keep company with a woman so conditioned? But, says he (Manec), if she was not a woman, Valmont was a man, for it is necessary to place him somewhere and to assign to him some function? Without doubt, it is necessary to place him somewhere and to assign to him some function. Nevertheless, it is neither that of a woman nor of a man in all its purity. He is a compound of a man and a woman, a kind of *third sex*, a *mongrel* or a *sexual mule*."

This discussion shows more forcibly than any remarks of my own the utter futility of attempting to find in the arrangement of the genital *passages* any feature absolutely distinctive of sex. Neither is there any certain arrangement of the accessory reproductive glands which can be regarded as peculiar to either.

We have seen that the glands of Cowper in the male hyæna exactly repeat those of Bartholini in the female in size, form, and mode of entrance into the uro-genital canal, and that therefore neither of these glands present any peculiarities distinctive of sex. At first sight, indeed, it appears that the presence of the prostate gland is sufficiently distinctive of the male mammal, but further consideration shows that such is not the case. The entire absence of the prostate gland in the males of many species of mammals (elk, red deer, &c.) shows that it is by no means an essential constituent of the male genital organs; whilst, on the other hand, although I am not aware of the existence of any female mammal in which a prostate gland is *constantly* present, yet the mere fact of its occasional occurrence in undoubted females of our own species at once destroys its value as affording an index to the sex of the individual in which it occurs. The gland is not uniformly present in the male mammal, neither is it always absent in the female, and consequently cannot, in any way, be regarded as distinctive of either sex.

We are, therefore, compelled to look elsewhere for a distinctive sexual characteristic. This is to be found in the histological structure of the genital *gland*, and in this *alone*. The presence of a genital gland presenting the structure of the testicle is the *single* distinctive characteristic of the male, just as the possession of an organ displaying the histological characters of the ovary is the *only* certain guide to the determination of the female sex. The late Sir J. Y. Simpson, in his remarkable article on Hermaphroditism, in Todd's *Cyclopædia of Anatomy*, divides hermaphrodites into two classes, *spurious* and *true*. With the former we are not now concerned. The latter group he subdivides into three subordinate sections—(1) *Lateral* hermaphrodites, in which there is a testicle on the one side of the body and an ovary on the other; (2.) *Transverse* hermaphrodites, in which the external organs are those of the male and the internal those of the female, or the reverse; (3.) *Vertical* or *double* hermaphrodites, in which there are present (*a*) Ovaries associated with combined male and female passages, (*b*) Testicles with a similar combination, (*c*) Ovaries *and* testicles co-existing on one or both sides.

A consideration of the facts set forth in the preceding pages

shows that the group of *lateral* hermaphrodites, as above defined, is the only one to which the term *true* can, with propriety, be applied, whilst all the others ought to be included in the much larger section of *spurious* hermaphrodites, with the doubtful exception of subdivision (*c*), which, viewed in the light of embryological research, ought probably to be placed in the category of double monsters.

In conclusion, I have to acknowledge, with many thanks, the kindness of my friend Dr Alfred Young in reducing and adapting the various illustrations which accompany this paper.

Explanation of Plate III.

Fig. 1. Bifurcated vesicula prostatica of beaver (Leuckart). Fig. 2. Bifurcated vesicula prostatica of ass (Leuckart). Fig. 3. Vesicula prostatica of goat, showing separation into uterine and vaginal portions (Leuckart). Fig. 4. Female organs of hare (Owen). Fig. 5. Female organs of Indian elephant (Miall). Fig. 6. Female organs of opossum (Owen). Fig. 7. Uterus of cow laid open (Owen). Fig. 8. Double uterus and vagina of child. The two halves are quite separate, as in the opossum. Fig. 9. Double uterus and vagina of human female. The two halves are united (Küssmaul). Fig. 10. Double uterus, with incomplete duplicity of vagina of human female (Küssmaul). Fig. 11. Uterus of human female, showing single corpus uteri and two cornua (Farre). Fig. 12. Another example of the same (Küssmaul). Fig. 13. Large vesicula prostatica of human male resembling the female uterus. The lower portion represents the vagina (Franque).

Explanation of Plate IV.

Fig. 14. Another view of Franque's case of large vesicula prostatica. Fig. 15. Uterus of calf, showing the canals of Gaertner on either side (Kobelt). Fig. 16. Lateral view of the erectile structures in human female (Kobelt). Fig. 17. Penis of koala, showing bifidity of bulb and glans penis (Young). Fig. 18. Generative organs of Maria Arsano (Simpson). Fig. 19. Female organs of Stenops, showing perforation of clitoris by urethra (Vrolik). Fig. 20. Male organs of *Hyæna crocuta*. Fig. 21. Female organs of *Hyæna crocuta*. Fig. 22. Generative organs of Valmont (Bouillaud).

PORI ABDOMINALES OF VERTEBRATA. By

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THE investigations as to the nature and distribution of the abdominal pores of Vertebrata, of which the following paper gives the results, were undertaken at the suggestion of Mr F. M. Balfour of Trinity College, Cambridge, and I have to express my thanks to him for the readiness with which he placed such of his material as was of use to me at my disposal. I would also wish to express my deep obligations to Dr Eisig and the authorities of the Stazione Zoologica at Naples for their exertions in supplying me with numerous specimens during the time that I occupied the table assigned to the University of Cambridge.

The topography of the various structures connected with the pori abdominales, to which attention is directed in the following paper, will perhaps be more clearly understood if I give a brief account of them as they occur in the male of the common Dog-Fish (*Scyllium canicula*), fig. 1.

In this Shark the perivisceral space forms a single cavity throughout the greater part of its extent, though dorsally it is partially divided into two halves by the much fenestrated mesentery that connects the alimentary canal to its dorsal wall. At a point corresponding to the origin of the ventral fins, and immediately in front of the cloaca, the body cavity retains its embryonic subdivision into two distinct peritoneal pouches. When traced backwards the two pouches rapidly diminish in calibre, and, passing on each side of the cloaca, curve downwards and terminate in the conical papillæ, which, on external examination of the cloaca, may be seen to project from its dorsal wall. Examination of the cloaca shows that it receives at its anterior end the anus; behind the anus is the single, median and papilliform outgrowth of the dorsal wall of the cloaca on which is situated the orifice of the urinogenital cloaca, into which the Wolffian ducts and ureters open; and still more posteriorly are the paired

papillæ, in which the two peritoneal pouches end cæcally. From a median ridge of the dorsal wall of the cloaca a fold passes on each side, at first backwards, and then curves forwards to end on the lateral margins of the ellipsoidal cloacal orifice. The two crescentic folds divide the cloaca into an anterior compartment which receives the rectum and the urinogenital ducts; and a posterior division, in which are situated the peritoneal papillæ. At the base of, and immediately behind, each papilla there is a small cæcal involution of the cloacal wall. This involution and the cavity of the papilla somewhat overlap one another—the former projecting inwards dorsad of the latter. The cæcal involutions—which will be subsequently referred to as the cloacal pits—end quite blindly, having no communication with the peritoneal pouches. The papillæ, or peritoneal papillæ as I shall in future call them, are also quite imperforate.

We may now examine the condition of the peritoneal papillæ and cloacal pits in the various families of the Elasmobranchii.

ELASMOBRANCHII.

SELACHOIDEI. SCYLLIIDÆ.—As has already been described, *Scyllium canicula* has both imperforate cloacal papillæ and blind cloacal pits; there are therefore no abdominal pores. Careful injection of the papillæ with coloured injection and with mercury from the abdominal cavity, readily caused them to become distended; but there was not the slightest escape of injection or other indication of the existence of pori abdominales. Microscopical examination of the apices of the papillæ and the pits led to the same conclusion. I examined a large number of specimens of both *Scyllium canicula* and *Scyllium stellare*, male and female, with precisely similar results. The three specimens of *Pristiurus melanostomus* that I examined agreed substantially with Scyllium. Imperforate peritoneal papillæ were present, and the cloacal pits, though absent in the male, were present in the form of very shallow depressions in the female.

In a young specimen of *Stegostoma tigrinum* the papillæ and pits exactly resembled those of Scyllium, and, as in the latter, both were imperforate.

In a small male example of *Chiloscyllium indicus* the pores were absent, though the papillæ and pits were very evident.

CARCHARIIDÆ.—In a male specimen of *Carcharias glaucus*, about five feet in length, the peritoneal papillæ were very considerable teat-like projections, three-quarters of an inch long. The apices of the papillæ were perforated by relatively small pores, but there were no traces of cloacal pits.

In an example of a male *Galeus canis* I found distinct peritoneal papillæ overlapping the cæcal cloacal pits. The right papilla had its apex perforated by a large abdominal pore, but the left one was quite imperforate.

In *Mustelus vulgaris* (female) the papillæ are rather large, with blunt apices; and on injection a very minute pore became apparent at the apex of each of them. The cloacal pits were so shallow as to be scarcely recognisable. The crescentic fold which was mentioned in the description of Scyllium as marking off the anal and urinogenital segment of the cloaca from the posterior division, is unusually well marked in Mustelus. In a male embryo of the same species, about six inches long, the papillæ were quite impervious to injection from the body cavity.

Pores are also present in *Carcharias melanopterus*.

NOTIDANIDÆ.—In the single specimen of this family which I have been able to examine,—a female of *Notidanus cinereus*,—the peritoneal papillæ were swollen and baglike, but injection failed to demonstrate the existence of any pores by which their cavities could communicate with the exterior. There were no cloacal pits.

CESTRACIONTIDÆ.—In two young specimens of *Cestracion phillipi*, 15 inches and 12 inches in length respectively, and of the female sex, the small peritoneal papillæ and cloacal pits were situated at the mesial ends of two crescentic furrows that crossed the cloacal roof. Both the papillæ and the pits were quite imperforate.

SPINACIDÆ.—Of several adult specimens of *Acanthias vulgaris* that I examined—nearly all were females, in which the condition of the papillæ and the cloacal pits seemed to depend on the sexual condition of the particular specimen. In one specimen—a female in which the oviducts were distended with embryos 8 inches long—I found well-marked papillæ and shallow cloacal pits. The left papilla was perforated by an abdominal pore with ragged and vascular edges, but the right

one was imperforate. In one of the embryos taken from the oviduct of this specimen, the right papilla was also imperforate, though the left one had a small pore. In a second gravid female, in which the embryos were 12 inches long, two large, widely open, slit-like pores with ragged edges had entirely obliterated all traces of papillæ and pits. Of the three embryos taken from the oviducts of this specimen, one, a male, had large slit-like pores and no pits; the second, a female, had perforated papillæ and small pits; while in the third one no trace of pori abdominales could be detected.

The effect of the sexual condition of the specimen on the condition of the papillæ and pores was well shown in these specimens of the viviparous female of *Acanthias vulgaris*. The distension of the oviducal walls by their contained embryos leads to general dilatation of the abdominal walls, to enlargement of the orifices of the Müllerian ducts, and to distension and turgescence of the peritoneal papillæ with enlargement of the pores. Hence, in non-gravid female specimens and in males well-marked papillæ, abdominal pores, and shallow cloacal pits are generally present. On the other hand, in gravid females, and especially in those in which the embryos are of a large size, the papillæ and small pores are replaced by exceedingly large pores with ragged and highly vascular edges. I have no doubt that similar variations will be found to occur in the females of other species of Selachians, and especially in the viviparous forms. Nor is it altogether improbable that pores may be temporarily present in the females of those genera in which I have hitherto failed to detect them—at all events in their breeding season.

In a male *Spinax niger* there were well-marked, slit-like pores, but no distinct papillæ.

Turner,[1] in his description of *Laemurgus borealis*—the Greenland Shark—says that in a female specimen of that Shark the abdominal cavity terminated posteriorly in funnel-shaped and somewhat twisted peritoneal pouches, which were prolonged on each side of the rectum to round pori abdominales opening into

[1] *Journal of Anatomy and Physiology*, vol. vii. p. 242, and vol. xii. p. 605. In the paper on this shark in vol xii., Turner describes a pair of oviducts as present, and explains how they had not been recognised in the specimen first dissected.

the cloaca; each pore was protected by fimbriated processes of the soft integument.

In a male[1] of the same species the abdominal pores were transversely elongated orifices.

The same writer[2] describes the Spiny Shark (*Echinorhinus spinosus*) as possessing two pori abdominales, each large enough to admit a catheter.

RHINIDÆ.—In a female specimen of the Angel-Shark (*Rhina squatina*) there was a small papilla on the right side and behind it a very shallow cloacal pit; but on the left side the cloacal wall was quite unbroken by either outgrowth or ingrowth.

In a young male about 12 inches long, I found small papillæ and obliquely disposed slit-like cloacal pits. In both specimens the pits and peritoneal papillæ were imperforate.

BATOIDEI. TORPEDINIDÆ.—In *Torpedo narce* the pori abdominales are lateral slits situated one on each side of the hinder margin of the cloaca; they open directly on the external surface and not into the cloaca; internally they open widely into the body cavity. There are no papillæ.

In *Torpedo marmorata* the external slit-like orifices lead into cloacal pits, which open into the body cavity by a very small orifices.

RAIIDÆ.—In the common Skate (*Raia batis*) the pores are large, somewhat obliquely disposed, slits situated to the outer side of the hinder margin of the cloaca; they open widely into the perivisceral cavity.

In a male specimen of *Raia clavata* I found, in the same position, deep cloacal pits; the one on the right side ended blindly, but the left one communicated with the body cavity through a minute orifice in its anterior wall. There were no papillæ.

In three specimens of *Raia maculata*,—two males and one female,—that I examined, there were slit-like orifices on each side of the cloacal opening which led into tolerably deep cloacal pits, but there was no communication between the pits and the body cavity. There were, therefore, no abdominal pores in this specimen.

[1] "Additional Observations on the Anatomy of the Greenland Shark" (*Laemurgus borealis*), *Journal of Anatomy and Physiology*, vol. viii. p. 289.

[2] "Observations on the Spiny Shark" (*Echinorhinus spinosus*) *Journal of Anatomy and Physiology*, vol. ix. p. 298.

In *Raia marginata* there are cloacal pits communicating with the body cavity by pori abdominales in their dorsal walls. No papillæ were present. Two specimens, a male and female, were examined.

Raia punctata very much resembled the last-mentioned species in the condition of its pores.

In *Raia miraletus* the cloacal pits appeared to communicate very widely with the perivisceral cavity.

TRYGONIDÆ.—In a female *Trygon pastinaca* I found short, conical, peritoneal papillæ, and behind them relatively deep cloacal pits. Both papillæ were perforated by abdominal pores, though the right pore was very much smaller than the left. In a male of the same species both papillæ were perforated by abdominal pores, but the pits were shallow. In another species (*Trygon brucco*), though a perforated papilla and a small pit were present on the right side, an imperforate cloacal pit only could be detected on the left side.

MARSIPOBRANCHII.

I am able to confirm the account given by Ewart[1] of the abdominal pores in the Lamprey and in Myxine. In the former the two efferent ducts of the kidneys, or segmental ducts, unite behind the anus and form a pear-shaped sinus, the external opening of which is situated at the apex of a well-marked papilla, to be seen projecting from the bottom of a shallow elliptical fossa common to it and to the more anteriorly situated anus.

Each posterior horn of the perivisceral cavity communicates with the exterior by means of a slit-like perforation in the side walls of the pear-shaped sinus; so that a probe introduced into the sinus through the external orifice at the apex of the papilla may be passed into either of the segmented ducts, or through the slit-like openings into one of the lateral halves of the body cavity. In the Lamprey, therefore, there are two pori abdominales which communicate with the exterior by a short sinus-like canal common to them and to the segmental ducts. In the male the papilla is long, somewhat curved, and has a

[1] "Note on the Abdominal Pores and Urinogenital Sinus of the Lamprey," *Journal of Anatomy and Physiology*, vol. x. p. 488.

very small orifice; but in the female it is short, thick, compressed laterally and almost straight, while the external orifice is a large oval opening. In the Lampreys distended with ova or semen the abdominal pores partake in the general distension of the adjacent parts, and are larger than at other times.

The disposition and arrangement of the pores and segmental ducts in the Myxine are substantially the same as in the Lamprey.

HOLOCEPHALA.

In *Chimæra monstrosa* the abdominal pores communicate with the two posterior horns of the body cavity by short though rather wide canals. The pores are situated just behind the anus and in front of the separate openings of the Müllerian and urinary ducts. There is no cloaca, the pores and the ducts having the same relative positions as their homologues in the Ganoidei and Teleostei.

GANOIDEI.

In three specimens of *Acipenser sturio,* all females, that I examined, the abdominal pores were very large slit-like orifices; they were situated immediately behind the anus, and in front of the single and median urinogenital orifice; internally they opened widely into the body cavity. There were no traces of peritoneal papillæ. As in all other Ganoidei, there is no cloaca, the urinogenital orifice and the pori abdominales opening directly on the exterior.

Günther[1] failed to find abdominal pores in a young example of *Acipenser sturio* (var. *A. oxyrhynchus*) 24 inches long; and in an example of *A. maculosus,* 20 inches long, he found one large pore on the left side, but none on the right. Wagner[2] makes a somewhat important statement with regard to the species *A. huso, A. stellatus,* and *A. ruthvenus.* He says that in these species, as well as in the Sturgeons generally (except *A. sturio*), the abdominal pores open into the ureters, and not directly on the exterior.

The pori abdominales of *Polyodon folium* are much the same as those of *Acipenser sturio;* they are simple, relatively wide

[1] "Description of Ceratodus," *Phil. Trans.*, 1871, p. 549.

[2] *Elements of the Comparative Anatomy of the Vertebrate Animals*, 1845.

canals, with obliquely disposed external orifices situated on either side of the hinder margins of the anus. In the particular specimen examined[1] the left pore was much larger than the right one, as also was the left Müllerian duct when compared with its fellow.

In the Teleostioid Ganoids the pores are much smaller than those of Acipenser and Polyodon. In *Amia calva* they are small round orifices situated on either side of the anterior part of the elongated fossa into which the anus opens. There are no papillæ or cloacal pits. The pores are precisely similar in both males and females.

From Hyrtl's[2] figures of the abdominal pores of *Polypterus*, it would seem that in this Ganoid they are somewhat papilliform, and situated rather in front of than behind the triangular anal orifice. The pores in a specimen of *Calamoichthys calabarensis* that I examined had much the same character, though there were no papillæ.

In *Lepidosteus osseus* the small pores are situated at the apices of well-marked papillæ, and lie on each side of the anus.

DIPNOI.

Ceratodus fosteri differs from existing Ganoids and from the other Dipnoids in that the rectum, and the dilated urino-genital clonaca which receives the Wolffian and Müllerian ducts, open into a large round cloaca. Abdominal pores are present in the form of exceedingly wide canals, that communicate with the exterior through crescentic widely open slits on each side of the posterior margin of the cloaca.

In *Protopterus annectens*[3] the disposition of the pores is somewhat different. The shallow cloaca has a small ellipsoidal aperture just behind the ventral fins. As in *Lepidosiren paradoxa* the cloacal orifice does not lie in the median line, but on the right side of a median and longitudinal fold of the integument. The two halves of the body cavity are quite distinct from each other for at least the posterior two-thirds of its extent; posteriorly they gradually contract into peritoneal canals, and after

[1] For the opportunity of examining this specimen I am indebted to the courtesy of Professor Macalister of Trinity College, Dublin.

[2] *Denkschriften der K. Akad. A. Wissensch Wien.*, vol. viii. Taf. iii. fig. i.

[3] Owen, "Description of Lepidosiren annectens," *Trans. Linn. Soc.* vol. xviii.

intercommunicating by an oval aperture, open outwards by a single external pore placed in front of the anus, but surrounded by the common cloacal sphincter. The ureters join the confluent oviducts, and the single urino-genital orifice is behind the anus.

TELEOSTEI.

Pori abdominales are present in three families of Physostome Teleostei—in the *Salmonidæ*, the *Murænidæ*, and *Mormyridæ*.

In the SALMONIDÆ the pores are present only in the females of the genus *Salmo*, and their presence is correlated with the absence of oviducts; in the male Salmo there are no pores, but the testes have proper efferent ducts.

In *Salmo salar* the pores are somewhat asymmetrically disposed; the left pore, which is small, is situated at the side of the anus, while that on the right side is very large, and lies rather behind the anus.

MURÆNOIDEI.—Abdominal pores are present in both males and females of *Anguilla vulgaris*, and have much the same character in both sexes. The two lobes of the kidney coalesce just in front of the anus, and form a median lobe, which extends backwards for some little distance into the tail. With the union of the kidney lobes their ureters also unite, and, after receiving a duct from the postanal segment of the gland, the common duct so formed dilates into a pyriform bladder, which curves downwards behind the rectum to an external orifice with prominent lips, situated just behind the vent.

The body cavity is also continued for some distance into the tail in the form of two postanal peritoneal pouches. Between the rectum and the common ureter a curious slit-like orifice in the contiguous limiting walls of the two pouches places them in communication with one another. This orifice may be compared to the similar aperture which, in *Protopterus*, connects the two peritoneal canals. Furthermore, the two peritoneal pouches communicate with the exterior by a single pore which opens just within the external orifice of the common ureter. In the opening of its pores into the terminal segment of the urinary duct the Eel bears some resemblance to the Lamprey.

The disposition of those structures is much the same in the

Conger Eel (*Conger vulgaris*). There is a shallow cloacal fossa, and at the bottom of it two openings may be seen; one is the common orifice of the urinary ducts and the *single* pore; the other is the anus. A wide slit allows the two peritoneal pouches to communicate with one another just behind their common opening within the urinary aperture. I regret that lack of examples prevented me examining the condition of those parts in Muræna, Ophichthys, Muræenesox, &c., and in the Gymnotidæ.

MORMYRIDÆ.—Hyrtl[1] first discovered the co-existence of pori abdominales and true generative ducts in *Mormyrus oxyrynchus*, and, from an examination of a specimen of this fish, I am able to confirm the correctness of his account. In my specimen—a male—the pores much resembled those of the Sturgeon; they were relatively of large size, and were situated in each side of the posterior margin of the vent. The left testis and the efferent duct with its external opening were distinct enough, and in structure and relations resembled those of other Teleostean Fishes, but of the right testis and its duct I could detect no trace whatever.

AMPHIBIA.

Specimens of *Rana, Bufo, Triton, Proteus, Siren, Siredon*, and *Menobranchus* were examined, but nothing of the nature of pori abdominales, peritoneal papillæ, or cloacal pits could be detected.

CHELONIA.

The peritoneal canals and cloacal bladder of the Chelonia have been described by Dr Anderson in an interesting paper in the *Journal of the Linnean Society*, vol. xii.

The body cavity in these Reptilia terminates on each side of the neck of the bladder in two slender peritoneal canals; these canals, which are capable of considerable distension, traverse the inside of each corpus cavernosum of the penis or the clitoris, and finally terminate, without any diminution in capacity, at the base of the glans, both of the penis and clitoris. As to the termination of these peritoneal canals opinions have differed. Cuvier[2] described each peritoneal canal of the male Tortoise as

[1] *Denkschriften der K. Acad. Wess. Wien*, vol. i.

[2] *Anat. Comp.*, vol. v. p. 114.

terminating in a cul-de-sac at the base of the glans. Is. Geoffrey St Hilaire and Martin,[1] from injection experiments on *Testudo indica* and *Emys trijuga*, arrived at the conclusion that each peritoneal canal at its extremity divides into two branches, one branch opening into the cavity of the cloaca at the base of the glans, and the other terminating in the vascular channels of the corpora cavernosa and the glans. These experimenters found that injection of mercury into the peritoneal canals was followed by inflation of the corpora cavernosa, as well as by escape of the injection through minute orifices at the base of the glans. From his injection experiments with water coloured by carmine, Anderson concludes that the connection which Geoffrey St Hilaire and Martin believed that they had established between the peritoneal canals and the blood spaces of the cavernous bodies was due to extravasation of the injection. He states that in his experiments the injection never entered the corpora, but in nearly all cases escaped by a minute simple or papilliform orifice at the base of the glans. These apertures are found, without distinction of sex, in *Geoemyda grandis*, *Emys hamiltonii*, *Trionyx ocellatus*, *Trionyx gangeticus*, *Batagur thurgi*, *Chitra indica*, *Emys trijuga*, *Emys platynotus*, and *Batagur lineata*; and as some of these forms belong to widely separated groups of Chelonia, it may be fairly assumed that they are very extensively present in the group. Dr Anderson concludes that these orifices "are strictly homologous with the abdominal pores of Selachians and Ganoids."

In addition to pori abdominales, cloacal bladders are very generally present in this group. These bladders, which were first actually described by Bojanus,[2] are capacious sacs, opening into the cloaca near its anterior extremity, and internally projecting somewhat into the perivisceral cavity. Anderson finds that these bladders are developed in *Emys trijuga*, *E. crassicollis*, *Batagur dhongoka*, *B. lineata*, *B. fusca*, *B. ocellata*. *B. teramorei*, *Pangshura tecta*, *P. teutonia*, *P. Smithii*, *P, flaviventris*, *P. sylhetensis*, *Cuora amboinensis*, *Cyclemys dentata*, *Geoemyda depressa*, *G. grandis*, and *Platysternum megacephalum*. The inner walls of these bladders may be perfectly smooth, as in all

[1] *Ann. des Sc. Nat.* vol xiii. (1828), pp. 153, 201.

[2] *Anat. Testud. Europ.* 1819, 21.

the true Emydes and Batagurs, or covered with long villi, as in Pangshura, Cyclemys, Platysternum, and Geoemyda. Cloacal bladders apparently are not to be found, so far as Dr Anderson's researches go, in *Testudo, Pyxidea, Trionyx, Chitra,* and *Pelochelys.* No doubt they correspond to similar cæcal diverticula that are met with in Crocodilia, Lacertilia, and Ophidia, and it is possible that all these structures may be related to the cloacal pits of the Elasmobranch Fishes.

CROCODILIA.

The only other Vertebrata in which pori abdominales are known to exist are the Crocodilia. As in Sauropsida generally, and as in the Elasmobranchii, the urinary and genital ducts open into a cloaca. A transversely disposed projection of the dorsal wall of the cloaca divides the cavity into an anterior and a posterior division. The anterior compartment receives the rectum and the generative and urinary ducts.

The perivisceral cavity terminates behind in two narrow peritoneal canals, which are continued backwards and downwards on each side of the urinogenital division of the cloaca; essentially, they open externally by two small pores situated on the anterior wall of the cloaca at the base of the penis in the male or clitoris in the female. The pores, though they have prominent lips, are scarcely papilliform. The above description applies to a species of *Alligator.* In a species of *Crocodilus*—a male—I found a somewhat different condition of things. The peritoneal canals terminated in two small projecting papillæ at the base of the penis—but as the apices of these papillæ were quite imperforate, there were no abdominal pores. Behind the papillæ of the Crocodile and the pores of the Alligator, there is a pair of deep cæcal, glandular pouches opening on the lateral walls of the cloaca, and much resembling in position and in other respects the cloacal pits of the Elasmobranchii.

It may be remarked that similar cloacal glands are very generally present in other Sauropsida, opening either into the cloaca or near its hinder margin.

SUMMARY AND CONCLUSIONS.

In Elasmobranchii may be noted the frequent coexistence of

two distinct cloacal structures—(1) paired outgrowths of the body cavity (the peritoneal papillæ); and (2) cæcal involutions of the epiblast from which the posterior and outer division of the cloaca is derived (cloacal pits). It would seem probable that in this group abdominal pores may be formed in two different ways—(1) by the perforation of the apices of the peritoneal papillæ, as in the majority of the Sharks and Dog-Fishes in which pores are present; and (2) by the perforation of the cloacal pits, as appear to be the case in the majority of the Skates and Rays. The pores, when present, are invariably situated posterior to the openings of the generative and urinary ducts, which lie between the former and the anus. In the Selachoidei the pores open into the hindermost division of the cloaca, but in the Batoidei they are situated altogether outside the cloaca.

Furthermore, it would appear that, of the specimens examined, the abdominal pores were altogether absent in three families (*Notidanidæ*, *Cestraciontidæ*, and *Rhinidæ*), and in at least four genera (*Scyllium*, *Pristiurus*, *Stegostoma*, and *Chiloscyllium*) of the Scylliidæ; that they may be absent in one species and present in other species of the same genus, as is evident from their existence in *Raia marginata*, *R. punctata*, and *R. miraletus*, and their absence in both sexes of *Raia maculata*. Pores may also be present in one individual and absent in another individual of the same species, as in young specimens of *Acanthias vulgaris* and *Mustelus vulgaris;* then, again, pores may be absent on one side of the cloaca and present on the other, as in specimens of *Galeus canis*, *Acanthias vulgaris*, and *Raia clavata*.

The pores also seem subject to much specific and individual variation, and their liabibity to a sympathetic variation dependent on the condition of the female organs is evident from the varying condition of the pores in gravid and non-gravid examples of *Acanthias vulgaris*. It is not clear that the presence or absence of the pores can be correlated with structural variations in other organs.

In the Marsipobranchii pori abdominales are certainly present in *Petromyzon* and *Myxine*. They open into a urniogenital sinus, and not directly on the exterior, and their presence is associ-

ated with the non-development of Müllerian ducts. In Ganoids the pores are invariably present, with the possible exception of certain species of *Acipenser* (Günther)? they open directly on the exterior, and not into a cloaca. They are large in the Selachoid Ganoids, relatively small in the Teleostioid forms, and papilliform in Lepidosteus and Polypterus only. They differ from the Elasmobranch pores in being situated in front of the urinogenital opening, and in the more specialised Ganoids (Amia, Polypterus) they have a tendency to get in front of the anus. No cloacal pits could be distinguished. On the authority of Wagner, it would appear that in certain species of Acipenser (*A. ruthvenus*, *A. stellatus*, *A. huso*) the pores communicated with the exterior by opening into the confluent unsplit portions of the primitive segmental ducts, as in the Marsipobranchii.

In the Holocephali pores are present in both sexes. In the relative position of their pores with regard to the urinary and generative openings, and in the absence of a cloaca, the Chimæroid Fishes resemble the Ganoid and Teleostean Fishes.

The Teleostei agree with the Ganoids in the disposition and nature of their pores, which are simple slit-like orifices, without peritoneal papillæ or cloacal pits. They are situated close behind the anus and in front of the urinary and generative apertures, but in the Eel open within the margin of the orifice of the urinary duct. There is no cloaca. The correlation of the pori abdominales with atrophy of the oviducts in the female Salmon, the absence of pores and the presence of generative ducts in the male Salmon, the existence of pores and absence of generative ducts in both sexes in the Eel, are noteworthy features. Finally, the undoubted co-existence of abdominal pores and true generative ducts in *Mormyrus oxyrynchus* is a potent argument against the otherwise reasonable idea—suggested by the complementary nature of their pores and ducts—that the abdominal pores of Salmo and Anguilla are atrophied Müllerian ducts. It may be remarked that in the Teleostei abdominal pores are only found in three families of Physostomi which are otherwise characterised by the possession of not a few embryonic features—the result of degradation, or the persistence of a primitive condition, or both. In their skeletal anatomy, and in their

soft parts, the Salmonidæ and the Murænidæ exhibit a far lower degree of specialization than do most other Physostomi.[1]

I may add, that I have examined various species of about ten genera of Siluroidei, but failed to find any indication of the existence of abdominal pores in that important group. Of the Dipnoi, *Ceratodus*, in having the pores on the hinder margin of a cloaca, and behind the urinogenital opening, repeats the Selachoid arrangement of those structures. *Protopterus*, in having a single pore in front of the anus, exaggerates a tendency observable in the higher Ganoids.

In the Sauropsida abdominal pores are present in two groups only (*Chelonia* and *Crocodilia*). Both these groups resemble the Selachians in (1) the co-existence of pori abdominales and cloacal pits; (2) the variable distribution of the pores and pits; and (3) in having a cloacal outlet for the pores, the rectum, and the urinary and generative ducts.

In certain groups of Sauropsida—the *Lacertilia* and the *Ophidia*—large and glandular cloacal pits only are to be found.

Function of the abdominal pores.—In the majority of Elasmobranchii the pores cannot function as efferent ducts of the generative organs, because proper generative ducts are almost invariably present. Nor is it at all easy to see that they can be of use to their possessors in any other way. The apparently arbitrary presence and absence of the pores, and their tendency to individual variation, are cogent reasons for believing that, whatever may once have been their functional importance, they are now merely functionless and rudimentary structures. It is not clear that the pores of the female Ganoids and Dipnoi, and those of both sexes in *Mormyrus oxyrynchus*, in Chelonia, and in Crocodilia, can subserve any very definite or important function. Generative ducts co-exist with the pores in Mormyrus, in Chelonia, and in Crocodilia; and in the two latter groups the existence of pores is far from being universal. In these forms, therefore, as in Elasmobranchii, the abdominal pores must be regarded as persistent rudiments.[2]

[1] For further discussion of this point see Balfour's paper on "Origin and History of the Urinogenital Organs in Vertebrates," *Journal of Anatomy and Physiology*, vol. x.

[2] Dr Günther has suggested that the pores in the Ganoids may be useful "for discharging semen or ova which have lost their way to the abdominal aperture of the oviducts."—"Description of Ceratodus," *Phil. Trans.* 1871.

It is an equally difficult matter to draw any definite conclusions as to the function of the pores in the male Ganoids, until the vexed question of the existence or non-existence of true vasa efferentia has been definitely settled. It may be that the failure of those who have investigated the urinogenital system of Ganoids to discover such efferent channels is really due to the absence of such structures. If this be so the pori abdominales must act as the efferent channels for the semen.

On the other hand, from all that can be legitimately inferred as to the phylogenetic relations of the Ganoidei, the probability that they do possess proper vasa efferentia, or, at all events, *did* once possess them, is exceedingly strong. In existing Elasmobranchs, in Amphibia, and in all the abranchiate Vertebrata, more or fewer of the anterior segmental organs act as efferent channels by which the semen is conveyed to the Wolffian ducts, and it is highly probable that a similar arrangement obtained in the common ancestors of existing Ganoids and Teleostei. But it may be that at a later stage in the evolution of the two last-mentioned groups, the anterior segmental tubuli lost their connection with the tubes, and were replaced as efferent ducts by the pori abdominales. This condition has been permanently retained by the majority of existing Ganoids, and possibly by the Dipnoi also. At a still later stage in the evolution of the Teleostei the Müllerian ducts became continuous with the investments of the generative glands, and served as vasa efferentia in the male, in addition to functioning as oviducts in the female, while the pores disappeared or became mere rudiments. In this way it may have happened, that while the Ganoids, with the exception of Lepidosteus, permanently retain the transitional condition of the first of the two last stages, Lepidosteus and the great majority of the Teleostei exhibit the last phase.

In the Marsipobranchii, in the female Salmon, and in the male and female Eel, the abdominal pores are the only channels by which the generative products are conveyed outwards.

I agree with Balfour[1] in regarding the abdominal pores as being structures perfectly independent of Müllerian ducts, and as homologous throughout the various groups of Vertebrata in which

[1] "Origin and History of the Urinogenital Organs of Vertebrates," *Journal of Anatomy and Physiology*, vol. x.

they occur. That the pores of the Salmonidæ and Murænidæ have no relation to Müllerian ducts is tolerably certain, for reasons previously given. That the Marsipobranch pores have any relation to aborted Müllerian ducts, as Gegenbaur has suggested, seems to me to be very improbable, though their real nature can only be understood when their development has been worked out. For the present, at all events, I am inclined to regard the Lamprey as exhibiting a lower stage in the condition of the urinogenital system than any other craniate Vertebrata—a stage in which the primitive undivided segmental duct persists as the efferent duct of the segmental tubuli, and pori abdominales function as the sole generative ducts.

As to the nature of the abdominal pores, I am inclined to agree with Balfour's suggestion,[1] that they may represent a posterior pair of segmental tubuli. This view is in harmony with the following facts:—

(1.) The anatomical relations of the pores. In most cases they are simple, paired outgrowths of the body cavity, connecting it with the exterior. In Vermes a segmental organ is the product of two distinct factors—an outgrowth of the body cavity, and an involution of the epiblast. Two similarly derived factors, the peritoneal papillæ and the cloacal pits, are intimately associated with abdominal pores, which, in fact, may be formed from either of them.

(2.) The existence of postanal segmental tubuli in the developing shark. A pair of these may persist and form the abdominal pores.

(3.) The abdominal pores, like true segmental organs, not unfrequently open into the unsplit posterior portions of the primitive segmental ducts—as in the Lamprey and as in various species of Acipenser.

To make it clear that the pores are so related to portions of the segmental duct, and not to any epiblastic ingrowth, I will give a brief sketch of the development of the cloaca.[2] In Scyllium, the first indication of an anus is the formation of a downgrowth of the primitive alimentary canal in the region of the

[1] *Loc. cit.*

[2] Balfour, *Monograph on the Development of the Elasmobranch Fishes.*

future anus, so that the former becomes divided into pre-anal and post-anal sections. Into this downgrowth or dilatation the segmental ducts open. At a somewhat later stage an involution of epiblast takes place, and by a perforation is placed in communication with that part of the gut which receives the segmental ducts. The cloacal pits are cæcal involutions of this epiblastic ingrowth. In the embryo Scyllium the segmental ducts open separately into the cloaca; but in the adult the Wolffian ducts and the ureters open into an unpaired urinogenital cloaca, which communicates on the one hand with the general cloaca by a single aperture situated at the apex of a papilla just behind the anus, and, on the other hand, with a pair of bladders situated in close contact with each other on the ventral side of the kidney. Of the unpaired urinogenital cloaca and the bladders, Balfour remarks that it seems probable that both are products of the lower extremities of the Wolffian ducts In the adult Scyllium, therefore, the cloaca is composed of (1) a dilated portion of the gut; into this the rectum and the confluent portions of the Wolffian ducts (the unpaired urinogenital cloaca) open; (2) an involution of epiblast, which forms the outer and hinder compartment of the cloaca. In relation with this second division, we have the peritoneal papillæ and the cloacal pits. The two transversely disposed crescentic ridges that traverse the dorsal wall of the cloaca would appear to correspond pretty accurately in position to the line of demarcation between the epiblastic and hypoblastic elements of the cloaca. Now, in the Elasmobranchs the pores invariably open into the epiblastic portion of the cloaca, and in most Ganoids, in Dipnoi, and in Teleostei directly on the general epiblastic surface of the body; but in the Marsipobranchii quite another arrangement obtains. In the Lamprey the rectum and the single orifice of the segmental duct open into a groove between two lateral downgrowths of the body wall, and the abdominal pores open into a sinus common to them and to the segmental ducts. I imagine that this sinus corresponds to the unpaired urinogenital cloaca, and, like it, is a product of the segmental ducts. Hence, in the Lamprey the pori abdominales agree with true segmental tubuli in opening into the segmental ducts. Finally, in the species of Acipenser previously referred to there is a similar

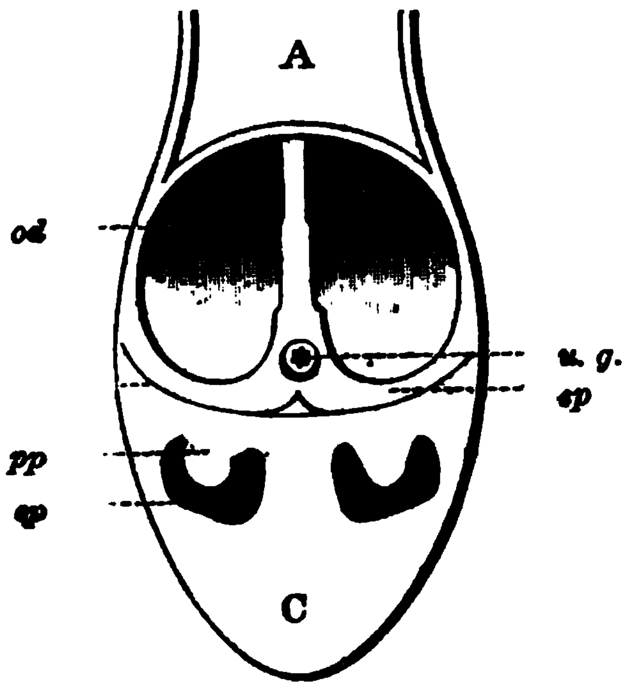
urinogenital cloaca which receives the ureters and Müllerian ducts, a certain number of the hindermost segmental tubuli, and, still more posteriorly, the pori abdominales. In the Lamprey and in these Sturgeons the pores behave exactly like proper segmental organs.

The presence of pori abdominales in various forms, and often as functionless structures, in such widely diverse groups as the Marsipobranchii, Elasmobranchii, Ganoidei, Teleostei, Dipnoi amongst the Ichthyopsida, and Chelonia and Crocodilia among Sauropsida, is clear evidence of their great antiquity and primitive functional importance. The key to their original function in the primitive Vertebrata is, I imagine, to be found in their condition and in their relations to the generative organs, and to the segmental ducts in the first-mentioned of these groups. In the Lamprey the pores resemble the other segmental tubuli in essential relations; they are diverticula of the body cavity and open into the segmental duct, but differ from them, however, in being simpler in structure, and in not possessing a glandular segment. This simplicity is to be accounted for by their functions in both sexes as efferent generative ducts. I would therefore regard them as a pair of posterior segmental organs, specialised in the primitive Vertebrata to the function of conveying the generative products to the segmental duct, and so outwards. This primitive condition has been permanently retained by the Lamprey. Eventually, in the higher forms, they were superseded by the Müllerian duct in the female, and by certain anterior segmental organs and the Wolffian duct in the male (Elasmobranchii, Amphibia, &c.), or by Müllerian ducts in both sexes (Teleostei). Nevertheless, in several of these groups we met with exceptional reversions to the primitive type. In osseous Fishes (Eel and Salmon), atrophy of the proper generative ducts is followed by renewed functioning of the pores; and it may be that, from a similar cause, the Ganoids also, while representing a transitional stage in the evolution of the Teleostean type from the Selachioid type of the urinogenital system, are dependent upon their pori abdominales for the escape of their sexual products.[1]

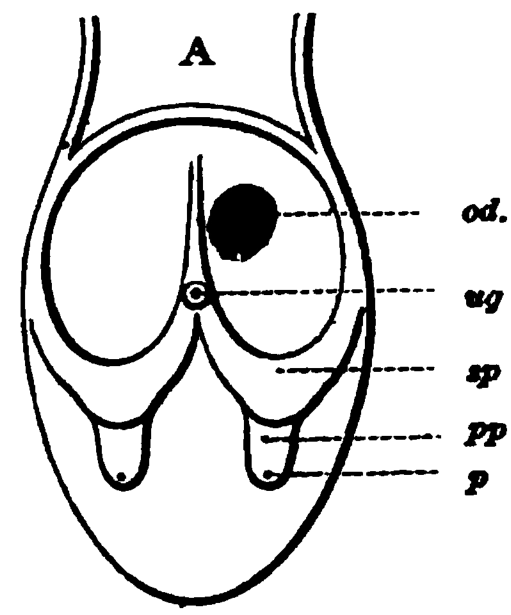
[1] Gegenbaur, in his *Grundzüge der Vergleichenden Anatomie*, has, I find, anticipated my suggestion that the pori abdominales were probably the sole efferent channels for the generative products in the primitive Vertebrata.

PLATE AND EXPLANATION.

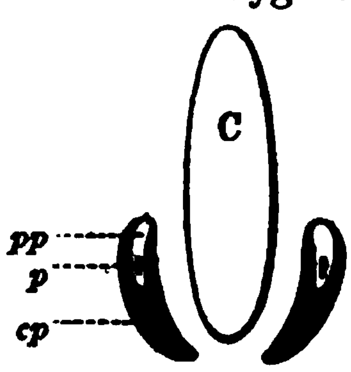
I. Scyllium canicula.



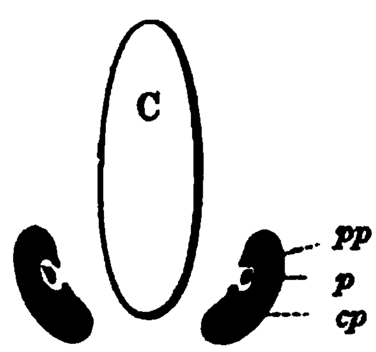
II. Mustelus vulgaris.



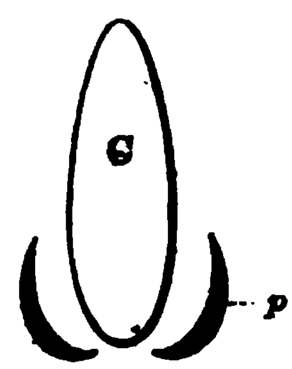
III. Trygon.



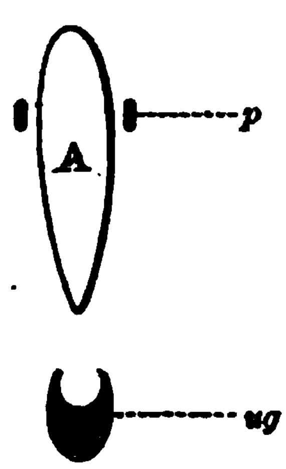
IV. Raia.



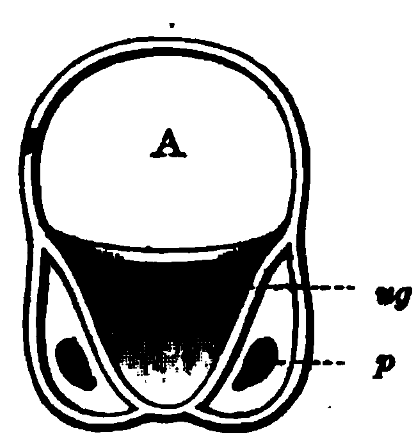
V. Torpedo.



VI. Amia calva.



VII. Ceratodus fosteri.



I. Scyllium canicula.
II. Mustelus vulgaris.
III. Trygon.
IV. Raia.
V. Torpedo.
VI. Amia calva.
VII. Ceratodus fosteri.

A. Anus.
od. Oviduct.
ug. Urinogenital orifice.
sp. Crescentic septum.
pp. Peritoneal papillæ.
cp. Cloacal pits.
p. Pori abdominales.
C. Cloaca.

ON THE PORI ABDOMINALES IN SOME SHARKS.

By Professor TURNER, M.B., F.R.S.

PROFESSOR BRIDGE having in the immediately preceding paper on the Pori Abdominales of Vertebrata referred to some observations of mine on these openings in the Greenland and Spiny Sharks, I may take this opportunity of extracting from my note-book some additional observations which I have made on these orifices in some other Elasmobranchs.

Scyllium canicula.—In September 1873, I obtained from the fisherman's nets in Loch Goil a specimen of this shark. Whilst handling it an egg, in its horny case, slipped out of one of the genital orifices, and a second case partially protruded. I carefully removed all the genital organs with the cloaca, and placed them in the Anatomical Museum of the University. The cloacal region presented the following arrangement:—The rectum opened into the anterior part of the cloaca. Behind it were the large openings of the two oviducts. Behind the oviducts was a crescentic fold, such as Prof. Bridge has described as the crescentic septum. Posterior to that were two short papillæ, one on each side of the middle line. At the summit of each papilla was an orifice, into which a bristle could easily be passed into a funnel-shaped prolongation of the peritoneal cavity situated at the side of the rectum. These orifices were therefore true abdominal pores. At the base of each papilla, and situated more especially at its outer border, was a shallow pouch-like depression of the wall of the cloaca.

This specimen differed, therefore, from the one described by Prof. Bridge, in which the papillæ were imperforate. It must be noted that his was a male, mine a gravid female, and the difference in the condition of the peritoneal papillæ may be, as he has surmised in *Acanthias vulgaris*, an effect of the sexual condition.

Acanthias vulgaris.—At the same time and place I obtained several specimens of this shark, five of which I preserved. In two females a pair of abdominal pores opened with slit-like orifices, and without papillæ, into the posterior part of the cloaca, whilst the oviducts, urinary papilla, and anus were situated anteriorly. In two males the pores also opened by slit-like orifices; but in a third male only the left pore was

patent, the right being closed up by a thin semi-translucent membrane. A fold of the membranous wall of the cloaca marked the anterior boundary of the pore in each of these sharks.

Lamna cornubica.—In November 1878 I purchased a male Porbeagle, 7 ft. 1 in. long. The cloaca was large, with the anus opening into it anteriorly. Posterior to this orifice, and in the mesial plane, was a large conical urino-genital papilla 1½ in. long. Posterior and lateral to this papilla were the two peritoneal papillæ, each of which projected ¾ in. from the wall of the cloaca. Each papilla was perforated at the apex by an abdominal pore, communicating through a canal in the axis of the papilla with a funnel-shaped prolongation of the peritoneal cavity at the side of the rectum.

In a female Porbeagle, purchased in 1874, which measured 3 ft. 5½ in. in length, the papillæ for the abdominal pores were about ¼-inch long, but the pores readily admitted a porcupine quill into the peritoneal cavity. This female has already been referred to by me in this *Journal*, May 1875, as having afforded a demonstration of the presence of a pair of spiracles in the head, a point in its anatomy which has frequently been disputed. In the large male Porbeagle, above referred to, I also recognised on each side of the head, 3½ in. behind the eyeball, a minute spiracular orifice. It was almost on a line with the upper border of the orbit, and immediately in front of a vertical line drawn upwards from the angle of the mouth. A bristle was passed through each of these openings into the cavity of the mouth. The presence of spiracles in the Porbeagle may therefore, I think, be regarded as established.

Carcharias, Sp. (?)—Two female embryoes, each 9¾ in. long. In the posterior part of the cloaca of each specimen was a pair of minute papillæ. When examined with a pocket lens each seemed as if it had a minute orifice at the summit. But when a syringe was introduced into the abdominal cavity and fluid injected backwards, none escaped from the apices of the papillæ. These structures were imperforate, therefore, and the appearance of a pore was in all probability due to the thinness of the tegumentary covering of the apex of the papilla, marking the spot where most likely an opening would have formed at a more advanced stage of development.

A DESCRIPTION OF A CLEFT STERNUM.

By Professor TURNER, M.B., F.R.S.

THE excellent account by Drs Gibson and Malet of the very interesting case of cleft sternum, observed by them in a living man, which forms the first article in the present number of this *Journal*, induces me to figure and describe a cleft sternum preserved in the Anatomical Museum of the University of Edinburgh.

This specimen was obtained by the late Professor Hughes Bennett from the body of a woman who died many years ago in the Edinburgh Royal Infirmary. The deformity had not been observed during life. The specimen was shown by Dr Bennett to the Physiological Society of Edinburgh, July 11, 1851,[1] and the late Mr Zaglas was appointed to report on the case. So far as I can ascertain, no description of the specimen was, however, published. When Herr Groux visited Edinburgh in 1857, the specimen, which corresponded so closely to the condition of his own sternum, was shown to and examined by him with much interest, and some account of the preparation was, I believe, written at that time by Dr Bennett in the album in the possession of Herr Groux, in which so many physicians had recorded their opinions regarding his case.[2]

The sternum was completely divided into two lateral halves, each of which articulated with a clavicle and with the cartilages of the seven true ribs. Each half of the sternum was sub-divided into a præ-, a meso-, and a ziphi-sternum. The ziphi-sternum was cartilaginous, but the other segments were ossified, though the articulation of the præ-sternum with the meso-sternum was not converted into bone. The two lateral halves were each 4¾ inches long, and of almost the same shape and size. The two præ-sterna and meso-sterna were separated by a wide gap, but

[1] *Edinburgh Medical Journal*, Oct. 1851, p. 395.

[2] Herr Groux extracted from his album, and published in 1857, under the title of *Abhandlungen und Notizen über E. A. Groux's Fissura sterni congenita*, Hamburg, a number of descriptions and observations on his case, drawn up by eminent physicians both on the Continent and in England, but this publication does not include a notice of the specimen above described.

opposite the articulations of the 4th pair of costal cartilages the two meso-sterna began to incline inwards towards the mesial plane, and on a line with the 7th pair of costo-sternal joints they articulated with each other mesially. The articular surfaces were coated with encrusting cartilage, and were retained in contact by a capsular ligament lined by synovial membrane. In the figure the ligament is represented as cut through, so as to show the cavity of the joint.

When the two halves of the sternum were drawn most widely asunder, the interval between them was 2⅛ inches at its widest part, opposite the two halves of the manubrium, and here the gap was not filled up by any membrane; but at and below a line on a level with the 2nd pair of costal cartilages a strong fibrous membrane filled up the interval. This membrane was attached

laterally to the inner border of each half of the sternum, where it was continuous with the periosteum. Below it was continuous with the ligament enclosing the inter-sternal joint already described, whilst above it terminated in a well-defined free border.

In this specimen the division of the sternum is apparently more complete than in Drs Gibson and Malet's case, in which the two halves of the bone are described as meeting in osseous union at the level of the upper surface of the 4th rib.

Complete or partial fissures of the sternum, associated with a perfect development of the tegumentary covering of the ventral aspect of the thoracic wall (and which are to be distinguished therefore from those cases of imperfect development of the ventral wall of the chest in which there is ectopia cordis), are not so uncommon as might at first sight be supposed. For in addition to Herr Groux's well-known case, to the cases recorded by Skoda, Wittstock, and Cullerier, quoted by Dr Allen Thomson in his description of Groux's case,[1] and to those described in this number of the *Journal*, other cases have been recorded.

Förster figures and describes[2] a preparation in the Pathological Museum at Göttingen, taken from a boy, aged six, in which the two halves of the sternum, though widely separated above, become fused together opposite the 4th intercostal space. Each half of the bone is for the most part ossified, and undivided into a præ-sternum and meso-sternum; but the ziphi-sternum is divided into two lateral halves. The inner ends of the costal cartilages blend directly with the sternum, and are not jointed with it by articular surfaces. The interval between the two halves of the bone is occupied by a strong fibrous membrane.

Dr Obermeier has also described and figured an example[3] in a man, aged twenty-three, which he observed in the Charité, Berlin. This case bears a strong resemblance to that of Drs Gibson and Malet. The interval between the two halves of the bone is wide above, but they become continuous with each other almost on a level with the upper border of the 4th pair of costo-sternal joints. The inner borders of the two halves of the

[1] *Glasgow Medical Journal*, April, 1858, p. 48.
[2] *Die Missbildungen des Menschen*, plate xviii. fig. 1, p. 104, Jena, 1865.
[3] Virchow's *Archiv*, xlvi. p. 209, plate viii., 1869.

sternum, together with the upper border of the body of the bone, after the junction of the two halves, have a lyre-formed figure. It is also very interesting to observe that in Obermeier's case a mesial fold of integument, resembling that seen in Drs Gibson and Malet's example, extended upwards from the umbilical region towards the ziphi-sternum.

In addition to these cases already recorded, I may mention that my colleague, Professor Douglas Maclagan, had under his care, some years ago, a middle-aged woman in whom the sternum was cleft in the greater part of its length, and the two halves were separated from each other by a well-marked depression. No account of this case has yet been published.

THE PHYSIOLOGICAL ACTION OF OZONISED AIR.

By JOHN BARLOW, M.D., C.M., M.R.C.S.E., *Muirhead Demonstrator of Physiology in the University of Glasgow* (Plates V. and VI.)[1].

SINCE the year 1867, when Professor Andrews established clearly the identity of a substance in the atmosphere which decomposed a solution of the iodide of potassium, with ozone, a great amount of time and attention have been paid to this subject. Attempts have been made by numerous observers to find out what connection, if any, exists between the presence of ozone in large quantities in the atmosphere and the occurrence of epidemics of catarrh and influenza, and between a diminished quantity of ozone and the prevalence of epidemics of cholera. Along with these investigations, which were mainly conducted by those in charge of the various meteorological stations, there have been others in which attempts have been made to observe the effect of ozone, artificially prepared, upon living animals, and from the results observed to state what would probably be the effect of the atmospheric ozone upon the health of individuals and communities.

Dr Ireland[2] appears to have been the first to publish in detail the results of experiments upon animals with ozone.

He prepared the ozone by mixing in a vessel two parts of powdered hypermanganate of potash with three parts by weight of strong sulphuric acid. This vessel had two tubes connected with it: one of these was in connection with a pair of bellows, the other with a Wolff's bottle filled with water. The Wolff's bottle was in communication with a glass vessel, the mouth of which was inverted over a plate containing hot water. Into this glass vessel, the animal to be experimented upon was introduced. By this arrangement the gas given off from the hypermanganate was forced, along with air, through water, through the flask filled with water, and into the vessel in which the animal was contained. "The water was used," he says, "for the purification of the ozone."

In his experiments upon mice, he noted quickening of respiration from the first. There was always excitement; death, when it

[1] From the Physiology Laboratory of the University of Glasgow.

[2] *Edinburgh Med. Journal*, vol. viii., 1862–1863, page 729.

occurred, was caused by exhaustion. In examining *post mortem* the mice which died, he found the venous blood to be lighter in colour than usual—and in one mouse the lungs slightly congested. A rabbit was placed in a hermetically sealed box having two little glass windows. This box communicated with the flask containing water. He found that the respiration was accelerated exactly one-third. There was no excitement observable. The temperature was lowered; before the experiment 36° C., afterwards 31°. When let out, the surface was warm, and it began to eat food. Another rabbit was introduced into the same box, and kept in it for four hours. A larger quantity of hypermanganate was employed. Respiration accelerated. No excitement, save a little towards the end. He notes also that the animal did not suffer much uneasiness. When removed from box, the animal was dull and exhausted, but able to walk. It was then killed, and thorax immediately opened. The heart was found to be beating, and the blood coagulated instantaneously in the pericardium when the aorta was cut. The arterial and venous blood preserved their distinctive hues—perhaps venous blood was a little redder than usual.

Portions of blood, brain, lungs, liver, &c. were tried with Schonbein's and Houzeau's tests, but no ozone detected except in lungs. "These," he says, "resemble the results of the exposure of animals to oxygen gas, which, however, is described as bringing on comatose symptoms. These experiments were performed most carefully, and all sources of complication avoided as carefully as possible; and as I felt satisfied of their correctness, I saw no reason to sacrifice the lives of more animals by repeating them."

He concludes that—1. Ozonised air accelerates the respiration, and we may infer, the circulation. 2. Ozonised air excites the nervous system. 3. Ozonised air promotes the coagulation of the blood, probably by increasing its fibrin. In the blood, however, ozone loses its peculiar properties, probably entering into some of the constituents of the circulating fluid. 4. Animals can be subjected to the influence of a considerable proportion of ozone in the air for hours without permanent injury; but in the end, ozone produces effects which may continue after its withdrawal, and destroy life.

Dr Richardson (*Brit. Assoc. Report*, 1865) states that the inhalation of air highly charged with ozone produces irritation of mucous membrane of nostril, throat, and even congestion of lungs.

Dr Schwartzenbach found that death was produced in a rabbit in two hours after breathing air mixed with only $\frac{1}{2000}$ of its weight of ozone.

Dr Redfern of Belfast has experimented with ozonised oxygen. He finds that the respiration for a very short time of oxygen containing about the $\frac{1}{240}$ part of ozone is certainly fatal to all animals. Death

is not due to closure of the glottis, for it occurs when a large opening has been made in the trachea. "It causes death by producing intense congestion of the lungs, with emphysema, and distension of the right side of the heart with fluid or coagulated blood. If ozone be respired in a dilute form, the animals become drowsy and die quietly from coma, the condition of the lungs and heart being the same, except that the emphysema is less marked.

Dewar and M'Kendrick (*Proc. Roy. Society*, 1873–74) experimented with ozonised air and ozonised oxygen upon frogs, birds, mice, rabbits, and on themselves. With frogs, the most marked symptom was the diminution in the frequency of respiration. A frog, which was breathing 96 times per minute in ordinary air, breathed only 8 times after being exposed for half a minute to the influence of ozonised air. At the end of 6 minutes, the animal was quite motionless, and the respiratory movements had entirely ceased. Eight minutes after the introduction of pure air, the respirations numbered eighty-five per minute.

With birds, the same diminution in the frequency of respiration was noted. A linnet died after exposure for fifteen and a half minutes. A *post mortem* examination showed congestion of viscera—lungs of a dark purple colour and mottled—the heart pulsated feebly after systemic death, and was filled with venous blood. The blood corpuscles, examined microscopically, were normal.

With rabbits, there was also a diminution in the frequency of respiration (from 100 or 110 to from 36 to 30 respirations per minute.)

Dr Day (*Address on Ozone*, 1878) publishes the result of experiments upon animals which were made to breath ozonised air, "the oxygen in the air having been ozonised to the twelfth part." He noticed first irritation of nose and conjunctiva, free secretion of saliva, and profuse sweating. "There was also thirst and dryness of tongue and nostrils." These symptoms were succeeded by great *rapidity of respiration*, and soon by *violent action of the heart.* Death occurs from bronchitis or from pneumonia.

From these experiments it will be seen that there is a difference of opinion as to the effects produced by the breathing of ozone. Some regard it as a gas which may be breathed in considerable quantities without producing any permanent injury; others, as a gas which produces marked symptoms, and even death. Among the latter class of observers, there is a difference of opinion as to the cause of death—whether due to asphyxia or to bronchitis, or to some special action on the blood and nervous system—and also as to the effect of breathing ozone upon the character and frequency of respiration. Influenced by these discrepancies, I determined to repeat and modify some of the experiments with ozone. The necessity for precise information as regards its action is at present very pressing. During the

last few years the inhalation of ozone has been recommended as a plan of treatment in diseases supposed to be due to a deficiency of oxygen. Lender (Tardieu, *Dict. of Hygiene)* has not only recommended it in the form of inhalation in tuberculosis, rheumatism, and asthma, but has established an ozone manufactory in order to have a large quantity of it constantly at his service.

The ozone used in the experiments was generated in the cheap and simple ozoniser recommended by Sir B. Brodie. A reference to Plate V. shows its construction at once.

It consists of a tube B, about 14 inches long, having a smaller tube *b*, in communication with its side, and another tube *c*, communicating with its bottom. Within the tube B is placed a second tube A, having near the top a slight shoulder blown upon it—the object of the shoulder being to rest upon the mouth of tube B. At this point of contact of the two tubes B and A, a thick coating of paraffin is placed, so that between B and A we have a space, communicating on the bottom with tube *c*, and at the side with tube *b*. Within tube A is placed water, and a wire communicating with the induction coil, and outside B we have a vessel of water containing the second wire from the induction machine. The ozone is formed, by the *silent discharge* of electricity, from the oxygen of the air as the air traverses the space between tubes B and A. The air, before it reaches the ozoniser, is thoroughly dried by passing through vessels C, C′, containing H_2SO_4 and glass moistened with H_2SO_4, and through D, containing sticks of KHO and solution of KHO, and D′ containing glass moistened with solution of KHO. After the air passes through the ozoniser it is again purified by passing through a tube-bulb containing KHO (E), This is attached to tube *b* on the one hand, and to the entrance tube of the box in which the animal to be experimented upon is placed, the object being to absorb the small quantity of nitrous acid which is formed along with ozone by the electrolysis of atmospheric air.

The box in which the animal is placed is seen in Plate V. The front and back of the box is made of glass. Two tubes open into the centre of each end, the one (*d*) for the entrance of ozonised air, the other (*e*) for the escape of air from the box. At the top of the box there is the opening through which the animal is introduced into the interior. This opening is closed, and the box rendered air-tight after its introduction, (1) by a sheet of thick india-rubber, having holes which pass over eight screws which surround the opening into the box; and (2) by a heavy brass plate *f*, having holes in the same positions. The brass plate and the india-rubber sheet are firmly brought into contact with the box by means of the eight nuts seen in the figure.

The arrangement for forcing air through the drying tubes, the ozoniser, and the box, is seen diagramatically. The only explanation of this arrangement which is necessary is that the portions of the

tubes which are *black* are composed of india-rubber tubing, and that g, g, g, g, g, g are clips.

Before reversing the positions of the bottles G and H we require to place the clips which, in the diagram surround glass tubing, upon the india-rubber tubing, and to place those which in the diagram constrict india-rubber tubing, upon glass tubing. Upon reversing the bottles fresh air is again forced through the ozoniser by the descent of the water from the upper to the lower bottle. Knowing the amount of water in the upper bottle we know how much air must be forced from the lower bottle, to make room for it. In the experiments there were 3 litres of water in the bottles. Six of Bunsen's elements were employed to work a powerful induction machine.

A few experiments were made with frogs, to notice the symptoms produced by the ozonised air, and more particularly the effect of breathing such air upon the frequency of respiration. The effect produced was that described by Dewar and M'Kendrick, as regards the irritating action of the air upon the eyes and nose. The frog rubbed its nose frequently, the eyes were closed, and the animal changed its position frequently. The effect upon the number of respirations was well marked. They were reduced from 100 to 20 per minute. After breathing the gas for ten minutes respiratory movements seemed to cease; but on closer inspection, there was seen to be slight swelling and flattening of the throat taking place with long and regular intervals. I never succeeded in killing a frog during the experiment, nor did I ever notice that the respiratory movements ceased entirely. Upon removing frogs from the chamber in which they had been exposed for half-an-hour to the action of ozonised air, they were found to be in a stupid condition, responding slowly to a stimulus. They however recovered quickly, and no bad after effects were noticed.

Rabbits were introduced into the air-tight box first to note the general effect of breathing ozonised air. The air was supplied to them at the rate of 1 litre in 2½ minutes.

EXPERIMENT I.—*December* 5, 1878.

A strong adult rabbit, weighing 1960 gram.; introduced into box at 7.43 P.M., and air admitted. 7.47 P.M., respirations 160 per minute, regular. *Induction machine set in action* 7.50 P.M., ozone apparent at exit-tube, but in small quantities; respirations 160, irregular. 7.53 P.M., respirations 120. 7.56 P.M., respirations 80; animal has rubbed its nose several times. 8 P.M., respirations 70. 8.4 P.M., respirations

65; irritation of nose continues; animal quiet, with head low. 8.8 P.M., respirations 45. 8.12 P.M., respirations 42. 8.16 P.M., respirations 40. 8.20 P.M., respirations 30; sneezing. 8.24 P.M., respirations 35, but not so deep as before. 8.30 P.M., respirations 35; the animal, except when rubbing its nose and sneezing, has been quiet. 8.35 P.M., *induction machine stopped and air supplied.* 8.37 P.M., respirations 40, very deep. 8.40 P.M., respirations 40, deep and regular. 8.46 P.M., removed from box. 8.52 P.M., respirations 90. 9 P.M., respirations 150. When the case was opened, touching the animal did not cause it to move; pupils presented their normal appearance. No indications of pain during experiment beyond irritation of nose.—December 7. Rabbit dead this morning. *Post-mortem* examination showed congestion of lower lobe of right lung; bronchi contains mucus.

EXPERIMENT II.—*December* 9.

Rabbit in poor condition, and weighing 1420 gram.; introduced into box at 11.30 A.M. 11.34 A.M., respirations 140; *induction machine worked.* 11.42 A.M., sneezing. 11.45 A.M., respirations 102; sneezing, and movements resembling "retching." 11.48 A.M., respirations irregular. 12.1 P.M., animal very restless, turning round in box frequently, and keeping its nose near the top of the box. 12.4 P.M., respirations 90. 12.7 P.M., respirations 85. 12.10 P.M., respirations 75. 12.14 P.M., animal since last note has been blocking up entrance tube, and thus preventing, to a certain extent, the entrance of the ozonised air; respirations 90. 12.18 P.M., has moved its position. 12.22 P.M., respirations 70. 12.26 P.M., respirations 65. 12.30 P.M., respirations 60. 12.31 P.M., *induction machine stopped and air admitted.* 12.33 P.M., respirations 80. 12.35 P.M., respirations 90. 12.40 P.M., animal removed from box; does not respond to any irritation applied to tail; weakness of extremities. The animal began to move about in two minutes, but it was very tremulous. 12.50 P.M., respirations 120, and the animal apparently all right.—December 10. Animal found dead this morning. *Post-mortem* examination showed deeply congested lungs but no consolidation.

Other experiments were made with rabbits, but the general results were the same as those given in Experiments I. and II. It was noted that in some cases the diminution in the number of respirations was followed by a slight increase, but this increase *was never so great as to make the number of respirations of ozonised air equal to that of breathing ordinary air.* This increase occurred at varying periods from the commencement of the experiment, the time of its occurrence being influenced apparently by the amount of ozone present. The greater the amount of ozone, the sooner this alteration in the frequency of respiration occurred.

The symptoms observed in these experiments differ widely

from those observed by Dr Ireland. After considering his method of generating ozone, and the means he employed to conduct that ozone to the animal, I am strongly of opinion that, in the experiments described by Dr Ireland, the animal was breathing an atmosphere containing a large amount of oxygen and little or no ozone. When the hypermanganate of potassium is acted upon by strong sulphuric acid, a large amount of oxygen is evolved, and a small part of this oxygen is in the condition of ozone. The method employed was one which generated ozone. This oxygen containing a small quantity of ozone was mixed with the air, forced into the vessel by the bellows, and passed *through water* to the chamber or vessel in which the animal was placed. This vessel also contained water. But according to Carius, ozone is soluble in water, 1000 volumes absorbing 4·5 volumes of ozone; and although this solubility of ozone in water is denied by Andrews, the latter is of opinion that water converts ozone into oxygen when agitated with it. So that, whether ozone is soluble in water or not, there can be no doubt that the small quantity of ozone, generated by the action of sulphuric acid upon the hypermanganate of potassium, would be further diminished during its passage through water, either by being absorbed by the water or by its being converted by the water into oxygen.

Attempts were made to estimate the amount of ozone present in the air supplied to the animal. The method adopted was as follows:—

The animal was introduced into the box, and ozonised air supplied at the rate of 1 litre in 2½ minutes. The ozonised air was forced into the box, and the air from the box escaped by the exit-tube. At certain periods in the experiment, a bulb-tube, containing a solution of iodide of potassium, was filled to the exit-tube, so that the air *from* the box before reaching the outer air was passed through the solution of the iodide. This bulb-tube remained attached to the exit-tube during the time taken to supply 3 litres of air to the box. The ozone present decomposed the iodine, and an orange coloration was produced, due to the liberation of iodine. The fluid in the bulb-tube was then placed in a beaker, and a solution of starch was added. A blue coloration was produced during the formation of the iodide of starch. This coloration was increased if, before adding the starch, a few drops of an acid solution, say of tartaric acid or sulphuric acid, were added to the fluid from the bulb-tube. In the decomposition of iodide of potassium by ozone iodine is set free, but there is apt to be formed iodate of

potassium, so that we would have in solution a mixture of iodide of potassium, iodate of potassium, free iodine, and caustic potash. Crum Brown (*Scot. Met. Soc. Journal*, 1869) showed, however, that "if a mixture of iodide and iodate of potassium be acidulated with a dilute acid, a quantity of iodine is set free exactly equal to what would have been set free by the ozone, supposing no iodate had been formed." The amount of iodine existing as the iodate of starch was estimated by adding to the solution, until it was decolorised, a standard solution of the hypophosphite of soda. By following this method I was able to estimate the amount of ozone, and its proportion in the air breathed by the animal.

EXPERIMENT III.—*December* 21.

Rabbit in good condition, weighing 1600 gram.; introduced into box at 10.50 A.M., and air admitted. 10.55 A.M., respirations 90–100. 10.58 A.M., *induction machine worked.* 11.12 A.M., animal has been very restless, and it has been impossible to count the respirations. 11.20 A.M., respirations 30. 11.30 A.M., respirations 60; very feeble and short. 11.35 A.M., great irritation of nose. 11.45 A.M., respirations 75. 11.50 A.M., respirations 75. 11.55 A.M., respirations 75. Ozone contained in 3 litres of air passed through solution of iodide of potassium, placed in bulb-tube and connected with exit-tube = ·137 gram., or 1 *part in* 28 *parts of air by weight.* 12·2 P.M., *induction machine stopped*, and rabbit removed from case; animal tremulous in its movements, but appeared to recover rapidly.—December 22. Animal found dead this morning. *Post-mortem* examination shows congestion of lungs, and bloody serum in pleural cavity.

From this experiment, then, we see that a rabbit which had breathed ozonised air for an hour died on the following day, and that the amount of ozone in the air which caused this result was 1 part in 28 parts of air. But the greater density and weight of ozone, as compared with air, led me to believe that the amount of ozone in the box would increase with the length of time during which ozonised air was passed through the box. This supposition was supported by the behaviour of the animal; for when the ozonised air was directed into the centre of the box, the rabbit raised its head, placed its nose into corners of the box, and finally give up the attempt to avoid breathing ozone; but after placing in the entrance-tube a piece of glass tubing, by means of which the stream of ozonised air was directed to the top of the box, the animal no longer raised its head, but placed it immediately under the entrance. To test this point I therefore performed the following experiment.

EXPERIMENT IV.—*December* 23.

Small rabbit, weighing 990 gram.; introduced into case at 12.50 A.M., respirations 70. 1 P.M., *induction machine worked.* 1.2 P.M., sneezing and retching; respirations 50. 1.3 P.M., *induction machine stopped,* and air admitted. 1.8 P.M., retching. 1.11 P.M., respirations 60. 1.16 P.M., *induction machine worked.* 1.19 P.M., irritation of nose, respirations irregular. 1.20 P.M., respirations 35. 1.24 P.M., animal restless, and movements irregular and uncertain; tumbled over in turning round. Amount of ozone in 3 litres of air collected at exit tube = ·066 gram., or 1 in 58 parts of air. 1.26 P.M., respirations 35; animal with nose at top of box (the ozone enters at centre). 1.30 P.M., respirations 35. 1.40 P.M., respirations 42; mouth open. 1.50 P.M., amount of ozone in 3 litres of air = ·19 gram., or 1 in 20½ parts of air. 1.57 P.M., *induction machine stopped.* Case opened, and rabbit removed; nose and lips blue; animal tremulous, and does not move for three minutes.—December 25. Animal dead. Congestion and consolidation of right lung (middle lobe).

But, it may be asked, Does the amount of ozone escaping by the exit tube represent the amount of ozone in the air which the animal breathed? Will not the amount be less, owing to the absorption of some of the ozone by the animal? It is doubtless true that some authorities have asserted that ozone in the atmosphere is absorbed, and enters the circulation along with the oxygen. It is difficult to believe that the inhalation of ozonised air as a remedial agent could have been recommended without such belief. But, on the other hand, the opponents of such a plan of treatment have asserted that the inhalation of ozone means the inhalation of oxygen, inasmuch as, they affirm, the ozone in contact with a living animal membrane would be converted into oxygen. But if ozone be absorbed as ozone, or be absorbed as oxygen after coming into contact with a moist animal membrane, we would expect that the air escaping from the exit tube would not at all accurately represent the amount of ozone in the air breathed by the animal.

The only way in which I could determine the amount of ozone entering the case, would have been some plan by which I could have introduced, between the tube-bulb for the absorption of nitrous acid and the entrance tube of box, another tube-bulb containing iodide of potassium. But this would have been very difficult, requiring, with the apparatus at my command, at least an interval of five or ten minutes to elapse.

Nor would such an arrangement have given to us correct

information as to the *quantity present in the air within the box,* because, as we have already seen, the ozone probably accumulates, owing to its greater density, in the box. The following experiment will, however, give us a fairly accurate means of answering the question raised:—

EXPERIMENT V.—*December* 26.

A small rabbit, weighing 1010 gram.; introduced into box, but not covered in, at 11.37 A.M.; respirations 70. 11.42 A.M., cover put on and screwed down, and the exit-tube plugged up. No air now enters the box, the object being to see what effect the breathing of impure air will have upon the animal. 11.46 A.M., respirations 60; eyes closed. 11.52 A.M., respirations 68. 11.55 A.M., respirations 66. 12 A.M., plug in exit tube removed, and air passed through. Animal, which has been in a lethargic condition, livens up and begins to breathe rapidly for a few seconds, and then regularly. 12.5 P.M., respirations 70. 12.7 P.M., *induction machine worked.* 12.11 P.M., sneezing; animal lying down at bottom of case (ozonised air enters at top); respiration 30. 12.15 P.M., respirations 40. 12.20 P.M., ozone in 3 litres of air passing from exit-tube = ·0258 gram., or 1 part in 150 by weight. 12.25 P.M., respiration 60. Amount of ozone in 3 litres of air = ·0589 gram., or 1 part in 66. 12.30 P.M., respirations 52–60, feeble. 12.40 P.M., respirations 60; feeble. Animal quickly removed from box, box closed, and ozonised air passed through it until 12.50 P.M., when the amount of ozone in 3 litres passing through case *without* rabbit in it = ·0887 grams., or 1 part in 43 parts by weight.

Now in this experiment, the rate at which the air passed through the box was the same as in Experiments III. and IV.; and yet, in these experiments we obtained from the air escaping from the exit-tube, at the end of 57 minutes in Experiment III., 1 part of ozone in 28 parts of air; and in Experiment IV., 1 in 58 parts at the end of 25 minutes, and 1 in 20 parts at the end of 50 minutes after the rabbit had breathed in the air. In Experiment V. we had, after removal of the rabbit, 1 *part of ozone in* 43 *parts of air.* Nor can the difference observed be due to a bad condition of the battery employed; for the analysis of the air, *when the rabbit was in the box* during the experiment, gave, at the end of 13 minutes, 1 in 150 parts, and at the end of 18 minutes, 1 in 66 parts. It may be urged that some ozone escaped from the box when the animal was being removed. This is quite possible; but the fact that the removal was affected as quietly and as quickly as possible, and the greater density of

ozone ($1\frac{1}{2}$ times that of air), would prevent any great disturbance of the contents of the box; and any disturbance which might have occurred would be more than compensated for, by the 7 minutes at least which elapsed after the closing of the case, during which the ozonised air was entering the box, before any analysis was made of the air leaving by the exit tubes. So that I am of opinion that the respiration of ozonised air does not, to any marked extent, affect the amount of ozone contained in such air.

Experiments were also made to determine what effect, if any, the breathing of ozonised air has upon the elimination of CO_2 from the blood. To effect this, the air escaping from the exit tube of the box, in which the animal was contained, was from time to time collected and analysed, and the amount of O and CO_2 estimated.

The apparatus for collecting and analysing the air is seen in Plate VI. It consists of a bottle A, inverted, having a hole at its upper part. This bottle communicates by means of india-rubber tubing with a tube B, graduated from above downwards in $\frac{1}{8}$ of a centimetre. This graduated tube is continuous with a bulb K, and through this with glass tubing L and H. The tube L, the bulb K, and the graduated tube filled to its lower part, contain 124 cc. When tube L and tube K are filled, and graduated tube filled only to the part next the bulb, 96 cc.

The tube at H is connected by means of glass tubing with the exit tube of air-tight box. At *c* there is a three-way stopcock, by means of which the air passing along tube H may, by changing position of stopcock, escape into outer air, may be passed along tube L, or air or fluid in tube L may escape into outer air.

Communicating with tube L are two tubes *d* and *d'*, which lead to the arrangement for the absorption of O and CO_2, the communication being opened and stopped by stopcocks *b* and *b'*.

The oxygen is absorbed in the following way:—A glass vessel F, containing a coil of fine copper wire, communicates by means of a piece of glass tubing with the bottle E, containing a strong solution of chloride of ammonium with free ammonia. The tube of communication dips below the surface of the solution. Communicating with bottle E we have a tube leading to an india-rubber bag, and containing air. By compressing the india-rubber bag when the communication of vessel F with tube L is open, the solution of chloride of ammonium is forced from bottle E through the tube into vessel F, and up to stopcock *b*. When we turn stopcock *b* so as to shut off communication with L, the vessel F remains full of fluid.

The arrangement for the absorption of CO_2 is the same, except that the fluid in bottle D is a stong solution of KHO, and that in vessel

G there are pieces of glass. Of course the apparatus must be rendered air-tight by means of india-rubber corks, and connecting india-rubber tubing must be wired.

The connection of tube H with exit tube of air-tight box, is made by having one glass tube sufficiently small just to pass within the other. A coating of paraffin at point of contact of the two tubes renders the joint air-tight.

This being the arrangement, let me describe, step by step, the method adopted in performing an analysis.

1. The vessels F and G are filled with fluid from bottles D and E. and they remain filled by turning stopcocks *b* and *b'*, so as to shut off communication with tube L. The bottle A is filled with water. The tube B, the bulb K, and the tube L are filled with water by raising bottle A and withdrawing stopcock *c*. When this is done, replace stopcock *c* so that all communication with tube H is shut off. The air from the box in which the animal is contained is now passing along tube H, through the stopcock *c*, into outer air. To analyse this air, lower bottle A. The tubes B and L, and bulb K remain filled with water until stopcock *c* is placed so as to establish communication with the air in tube H. Turn the stopcock *c* and allow the water to leave the bulb, and *the greater part* of the graduated tube. When this is done, turn stopcock *c* so as to shut off communication with tube H.

Raise or depress the bottle A until the fluid in the bottle A and tube B are at the same level. Read off carefully the height at which fluid stands in tube B. This gives the amount of air to be analysed. This being done, raise the water bottle and open stopcock *b*. The water rises in tube B, bulb K, and tube L, forcing the air present into vessel F. When the water fills the tube nearly to *d*, turn stopcock *b*, lower the bottle. Then open stopcock and the air from vessel F passes along tube L. To assist in the passage of the air from vessel F, the india-rubber bag is slightly compressed, so as to again force fluid from bottle E to vessel F. When this vessel is filled, the stopcock is again turned so as to shut off communication with tube L. This process may be again repeated. Then raise or depress the water bottle A until fluids are at same level, and read off height at which fluid in tube B stands. The difference between the two readings will represent the amount of oxygen which was present in the amount of air examined, the oxygen having been absorbed by the copper wire, moistened with chloride of ammonia.

To estimate the CO_2 the bottle A is again raised, stopcock *b'* opened, and the air forced into vessel G, where the CO_2 is absorbed by coming in contact with the glass moistened with KHO. The water bottle is lowered, the fluid from D made to fill G by compression of india-rubber bag *a'*. Stopcock *b* shuts off communication with L when G is filled. The water bottle A is raised or depressed until water is at the same level in bottle and in tube B. The height at which fluid in tube B stands is again read off, and the difference in this reading and the one made before CO_2 was absorbed gives the amount of CO_2 in the air examined.

Although from the description, the apparatus appears complicated, yet in practice the analysis of the air by this method is very simple and rapid. The amount of oxygen and of CO_2 in 100 cc. of air can be estimated in five or seven minutes. The fluids in bottles D and E requires to be replaced by fresh supplies after performing with them 30 or 40 analyses.

An experiment was first made to see the condition of the air in the air-tight box, no ozone being present, when a rabbit was contained in the box—to determine, in short, the standard of purity of the air, as regards CO_2, which I was capable of maintaining by means of the fresh air which was constantly being introduced.

Experiment VI.

Rabbit, weighing 1200 gram.; introduced into box at 10.50 A.M.; air contains 20·8 per cent. of oxygen. Air passing through at rate of 1 litre in 2½ minutes. 11 A.M., air contains 2·14 per cent. of CO_2, and 18·3 per cent. of O. 11.10 A.M., air contains 3·66 per cent. of CO_2, and 15·9 per cent. of O. 11.20 A.M., air contains 4·5 per cent. of CO_2 and 16 per cent. of O. 11·40 A.M., air contains 4·5 per cent. of CO_2 and 16·2 per cent of O.

This experiment was repeated two or three times with nearly constant results. I found that, by admitting air into the box, at the rate of 1 litre in 2½ minutes, the amount of CO_2 in such air did not rise above 4 or 5 per cent.

Experiments were next made to determine the effect, upon the amount of CO_2, of breathing organised air.

Experiment VII.

Rabbit, weighing 1200 gram.; introduced into chamber at 11.30, and air passed through: respirations 80. 11·45 A.M., 105·6 cc. of air contains 3·2 per cent. of CO_2 and 18·2 cc. of O. 12 A.M., 106 cc. of air contains 4 cc. of CO_2 and 18 cc. of O. 12.1 P.M., *induction machine worked.* 12.15 P.M., 105 cc. of ozonised air contains ·6 cc. of CO_2 and 21·6 cc. of O. Animal lying at bottom of box; respirations 32. 12.25 P.M., 106·8 cc. of ozonised air contains ·7 cc. of CO_2 and 22 cc. of O. 12.30 P.M., animal quiet with fore paws extended and head back; respirations 28, deep. 12.35 P.M., 106·2 cc. of ozonised air contains ·8 cc. of CO_2 and 22·4 cc. of O. 12.40 A.M., *induction machine stopped.* 12.50 P.M., 105 cc. of air contains 1·8 cc. of CO_2 and 21·8 cc. of O. 1 P.M., 104 cc. of air contains 1·8 cc. of CO_2 and 20·8 of O.

Experiment VIII.

Large rabbit, weighing 1800 gram.; introduced into box at 10·55 A.M., and air passed through. 11 A.M., 104 cc. of air contains ·4 cc. of CO_2 and 18·6 cc. of O. 11·10 A.M., animal quiet, eyes closed; respirations 70. 11·15 A.M., 102·4 cc. of air contains 3·2 per cent. of CO_2 and 17·2 cc. of O. 11.20 A.M., respirations 52, full and regular. 11·25 A.M., respirations 48. 11.25 A.M., 104 cc. of air contains 4.2 cc. of CO_2, and 16·6 of O. 11·35 A.M., respirations 48; animal quiet. 11.45 A.M., 103·6 cc. of air contains 4·2 cc. of CO_2 and 16·6 cc. of O. 11·55 A.M., 103 cc. of air contains 4·2 cc. of CO_2, and 16·5 cc. of O. 11.56 A.M., *induction machine worked.* 12 noon; salivation; mouth open; respirations cannot be counted, owing to movements of animal. 12.5 P.M., 103 cc. of ozonised air contains ·8 cc. of CO_2 and 21 cc. of O. 12.10 P.M., respirations feeble, and difficult to count. 12.20 P.M., 104·6 cc. of ozonised air contains ·8 cc. of CO_2 and 22·2 cc. of O. 12.35 P.M., 104·2 cc. of ozonised air contains ·9 cc. of O and 21·2 cc. of CO_2. 12.40 P.M., respirations laboured, 70. 12.45 P.M., 115 cc. of ozonised air contains ·9 cc. of CO_2 and 22·6 cc. of O. 12.46 P.M., *induction machine stopped.* 1 P.M., 104·2 cc. of air contains 1·2 cc. of CO_2 and 21 cc. of O. There is still a distinct smell of ozone in the air coming from stopcock *c;* respirations 60. 1.10 P.M., 103 cc. of air contains 3·2 cc. of CO_2 and 17·8 cc. of O. 1.20 P.M., 100·6 cc. of air contains 3·1 cc. of CO_2 and 17 cc. of O. Next day, the animal found dead; upon examination, lungs found congested, and bronchi filled with mucus.

Experiment IX.

Rabbit, weighing 855 gram.; introduced into chamber at 11.30 A.M. 11.45 A.M., respirations 140, shallow. 11.50 A.M., 107·8 cc. of air contains 3·5 cc. of CO_2 and 21 cc. of O. 12.5 P.M., 101·2 cc. of air contains 4 cc. of CO_2 and 19·24 of O. 12.6 P.M., *induction machine worked.* 12.10 P.M., animal lying down in box, sneezing; respirations 50. 12.14 P.M., respirations 45. 12.15 P.M., 100·2 cc. of ozonised air contains ·6 cc. of CO_2 and 19·4 cc. of O. 12·27 P.M., 101·8 cc. of ozonised air contains 1·8 cc. of CO_2 and 18·4 cc. of O. 12.30 P.M., respirations 50; animal drowsy. 12.40 P.M., 103·4 cc. of ozonised air contains 2 cc. of CO_2 and 20·4 of O. 12.50 P.M, 104·6 contains 2 cc. of CO_2 and 20 cc. of O; animal standing up, head elevated, and breathing very laboured. 1 P.M., *induction machine stopped.* 1.5 P.M., 103 cc. of air contains 3 cc. of CO_2 and 19.5 cc. of O. 1.15 P.M., 100·4 cc. of air contains 3·5 cc. of CO_2 and 17 cc. of O. There is still a smell of ozone at exit tube. 1.20 P.M., animal removed from chamber. This animal was found dead five hours afterwards. *Post mortem* examination shows congested lungs, blood venous, but not markedly so.

Experiment X.

A Guinea pig, weighing 575 gram.; introduced into chamber at 10.20 A.M. 10.27 A.M., 103·2 cc. of air contains 2·2 cc. of CO_2 and

18·6 cc. of O. 10.37 A.M., respirations 110–120. 11.10 A.M., 100·8 cc. of air contains 3·8 cc. of CO_2 and 16·6 cc. of O. *Induction machine worked.* 11.25 A.M., irritation of nose; irregular and spasmodic action of diaphragm. 11.27 A.M., 105·8 cc. of ozonised air contains ·6 cc. of CO_2 and 21·6 cc. of O. 11.37 A.M., 103 cc. of ozonised air contains 1 cc. of CO_2 and 20·2 cc. of O. 11·52 A.M., 99·2 cc. of ozonised air contains ·8 cc. of CO_2 and 20 cc. of O. 12.10 P.M., *induction machine stopped.* 12.30 P.M., the supply of air has been interrupted, in consequence of an accident, for three minutes. Animal lying on its side; respirations 60, irregular and laboured. 12.40 P.M., animal died, after slight convulsions. *Post mortem* examination shows congestion of both lungs; blood venous in colour in all parts.

From these experiments it will be seen that the breathing of ozonised air interferes greatly *with the elimination of carbonic acid.* The increase in the amount of oxygen is due probably to two causes—1st, a diminution in the amount of oxygen which is absorbed by the animal; and 2d, the fact, that the portion of oxygen which has been converted into ozone, coming in contact with the solution for the absorption of oxygen, would act like oxygen, and be absorbed by the solution.

This action of ozone in preventing the elimination of CO_2 was so striking, that I determined to contrast its behaviour with that of phosphuretted hydrogen. I arranged my apparatus so that I could, at will, pass a stream of air from the water bottles through the air-tight box, or could introduce into the box a small quantity of PH_3, which had been collected previously over water in a glass vessel. As I was able to dispense with the drying bulbs and the tube bulbs in this experiment, the air was forced through the box more rapidly than in the experiments with ozone, owing to the smaller resistance to be overcome. The apparatus for the estimation of O and CO_2 was connected with the exit-tube.

EXPERIMENT XI.

12·5 P.M., rabbit introduced into case and air admitted. 12·10 P.M., respirations 130, consisting of one or two slow, followed by seven or eight quicker respirations. 12·15 P.M., 100 cc. contain 20·6 cc. of O and 1·2 cc. of CO_2 12·18 P.M., respirations 140. 12·20 P.M., 103·6 cc. of air contains 1·4 cc. of CO_2 and 21 cc. of O. 12·27 P.M., a small quantity of PH_3 admitted, and supply of air stopped. 12·29 P.M., air admitted; respirations 190, regular and deep. 12·30 P.M., 104·4 cc. of air contains 1·2 cc. of CO_2 and 21 cc. of O. 12·33 P.M., respirations 150, not so deep. 12·37 P.M., respirations 160, shallow. 12·38 P.M., 102 cc. of air contains 3 cc. of CO_2 and 17·8 cc. of O. 12·43 P.M.,

animal apparently all right. 12·43 P.M., air stopped, and PH_3 admitted. 12·45 P.M., breathing nearly imperceptible, 114; animal lying down. 12·47 P.M., respirations shallow but regular, 90. 12·48 P.M., air admitted and examined; 103·4 cc. contains 1·4 cc. of CO_2 and 20·2 of O. 12·49 P.M., slow, deep, spasmodic respirations; 48 per minute. 12·50 P.M., convulsions. 12·57 P.M., convulsions and death. 12·58 P.M., air examined; 106·4 cc. of air contains 1·4 cc. of CO_2 and 21 cc. of O.

From this it will be noticed that with PH_3 there is a diminution in the amount of CO_2 given off, and this diminution is followed by an increase upon the admission of pure air. But this diminution is not of the marked character of that which is produced by breathing ozonised air. It is interesting to contrast the effect of the two gases upon the number of respirations. With ozone we have first a diminution, gradually increasing up to, but not attaining to the normal number; with PH_3 a decided increase at the first, followed by a diminution in the number of respirations.

In no experiment upon rabbits with ozonised air did I produce death of the animal, during the time it was in the air-tight box. In the case of a Guinea pig (Experiment X.), death occurred when the supply of fresh air was stopped.

I attribute this failure to produce death not to a deficiency in the amount of ozone (for the apparatus I employed was capable, as the analyses show, of generating a large amount), but to the rate at which air was introduced into the air-tight box.[1] This is merely an hypothesis upon my part, inasmuch as I have no means of knowing the exact amount of ozone used in the experiments by Dewar and M'Kendrick and the other observers, nor have I any means of knowing what was the condition of the air, as regards CO_2, of the chambers in which they performed their experiments. But in the experiments of Dewar and M'Kendrick, the *post-mortem* examination of the animals which died when breathing ozonised air showed appearances similar to those presented in cases of death from asphyxia.

Dewar and M'Kendrick (*op. cit.*, p. 218) say:—

"We can hardly avoid pointing out that oxygen in this altered condition ($O_3 = 24$) is slightly denser than carbonic acid ($CO_2 = 22$), and

[1] I am informed by Dr M'Kendrick that no estimate was made in the experiments made by himself and Mr Dewar.

that, although the chemical activity of the substance is much increased, yet when inhaled into the lungs, it must retard greatly the rate of diffusion of carbonic acid from the blood, which accounts for the venous character of that fluid after death. If, however, the physiological effect of ozone on respiration were due merely to its greater density, then we would expect its behaviour to be analogous to that of an atmosphere highly charged with CO_2. This has been found to be the case, more especially as regards the diminished number of respirations per minute and the appearance of the blood after death. If, however, this analogy were perfect, we would anticipate that the action of oxygen, partially ozonised, would not have produced death, as the amount of ozone in these experiments certainly did not exceed 10 per cent. As it was, all we have observed is that an animal only lives a somewhat longer time in ozonised oxygen than in ozonised air. We are thus induced to regard ozone as having some specific action on the blood, or on the reflex nervous arrangements of respiration."

Now, in all the experiments the reduction in the amount of CO_2 in the air from the air-tight box from 3 or 4 per cent. to ·6 or ·7 per cent. occurred before the induction machine had been working for fifteen minutes, when, as Experiment V. shows, the proportion of ozone would not exceed 1 part in 150 parts of air; and it is difficult to see how this amount of ozone, mixed with ordinary air, could, by the increased density of the mixture, produce such a diminution in the amount of CO_2. And this supposition is rendered more improbable by the fact that oxygen containing $\frac{1}{240}$th part of its weight of ozone produces death rapidly.

The condition of asphyxia might be due, however, to another cause—to a diminution in the amount of oxygen in the air, owing to some of it having been converted into ozone. Thus Dr Snow (Carpenter, *Human Physiology*, 8th edition, p. 423) observed that the presence of CO_2 in the atmosphere acts more deleteriously upon the system, in proportion as the normal quantity of oxygen is reduced. Thus various birds and mammals, introduced into an atmosphere containing only from $10\frac{1}{2}$ to 16 per cent. of oxygen, soon died, although means were taken to remove the CO_2 set free by their respiration as fast as it was formed. Now, the analysis of the air in the chamber showed the presence of 4 per cent. of CO_2 and 16 to 18 per cent. of O. The induction machine is worked, and a portion of oxygen is converted into ozone. The percentage of oxygen might from this cause be reduced below 16 per cent., and a fatal result might

arise, as in Dr Snow's experiments. But here, again, the death of mice in fifteen seconds (Redfern) and in forty-five minutes (Dewar and M'Kendrick) render this view improbable.

The difference in the time taken to produce death of mice by the respiration of ozonised oxygen in the experiments of Redfern, and Dewar and M'Kendrick, is very marked, and the observations can only be reconciled, either by supposing that the amount of ozone in the oxygen was greater in Redfern's experiment than in Dewar and M'Kendrick's, or, and what is still more probable, that the method of performing the experiment was different in the two cases. In Redfern's experiment the mouse was introduced into a vessel in which had previously been collected oxygen containing $\frac{1}{240}$th part of ozone. In the experiment of Dewar and M'Kendrick, the animal was placed in a vessel through which a stream of oxygen passed, and a portion of the oxygen was gradually ozonised by the ozoniser; and hence a considerable time would elapse before the oxygen had been ozonised, in the proportion even of 1 part in 240.

It has been suggested by Preyer that the blood corpuscles which contain O exert a chemical action by which CO_2, especially that existing in the serum, is liberated from stable compounds, and placed in a condition suitable for elimination. Does the inhalation of ozonised air or ozonised oxygen act upon the blood corpuscles in some way so as to prevent the liberation and elimination of CO_2? The answer to this question depends upon an answer to another. Is there any evidence that in the breathing of ozonised air or ozonised oxygen any of the ozone enters the circulation? In attempting to investigate this last question, I first made myself familiar with the changes which ozonised air produces upon the blood when brought into contact with it. Upon this point Doziel (*N. Rep. Pharm.*, xxiv. 231) says the action of ozone "is exerted chiefly upon the blood corpuscles, their colouring matter being separated and the blood becoming darker after a quarter of an hour. Defibrinated blood, exposed in their layers to the prolonged action of ozone, becomes brownish yellow, and does not yield any crystals of hæmoglobin on addition of alcohol, ether, or chloroform. On passing ozone for a long time through defibrinated blood, flakes are deposited, which, after washing with water, are undistinguishable from fibrin. The formation of this fibrin-like body is probably determined by an alteration of the hæmoglobin."

Dewar and M'Kendrick found that if blood was exposed upon

a glass slide to the action of ozone, changes similar to those produced by a weak acid, such as very dilute acetic acid or a stream of carbonic acid, were produced. The coloured corpuscles of man "become paler, lose their definite outline, and if exposed for a period of five or ten minutes to the action of the current, *they are dissolved, and a mass of molecular material is seen.* The coloured corpuscles of the frog show, after the action of ozone, the formation of a nucleus. By prolonged exposure, *many of the nuclei apparently pass out of the substance of the corpuscle, numerous free nuclei are seen,* and some in the act of *separating from the corpuscle* have been observed. The colourless corpuscles are collected into globular masses after the action of ozone."

In repeating these experiments with blood, I used the water bottles, the drying tubes, the ozoniser, and the tube bulb for the absorption of the nitrous acid. The tube-bulb was then brought into connection with one of the brass tubes of Stricker's hot stage. The stage was kept at a temperature varying from 38° to 40° C by a stream of hot water. And, in short, arrangements with the hot stage were made, similar to those made for examination of the movements of the colourless corpuscles and the effect of CO_2 on the blood—the only difference being that the blood was exposed to the action of a stream of air or ozonised air, instead of CO_2.

The tube supplying the air was compressed by means of a screw clamp, so that the air passed very slowly through the ozoniser and tube-bulb, and thus currents in the drop of blood were avoided.

A small drop of human blood was placed on the cover glass and mixed with a small drop of normal saline solution. This was placed on the hot stage, and examined with a power of 600 diameters, without any current of air or ozonised air. The object of this was to see if the arrangements I employed were fitted to keep the blood unaltered in appearance. At the end of ten minutes the coloured corpuscles were unaltered, and the appearance of the blood was unchanged.

A fresh drop was taken, and a very slow stream of air was passed over it. No change was observed. The supply of air remaining the same, the induction machine was worked. The

first change noticed was that the white blood corpuscles became globular; next the red blood corpuscles became colourless, these furthest from the objective, *i.e.*, nearest the ozone, being first affected. The liquor sanguinis remained colourless; next the white blood corpuscles lost their granular appearance in part, and showed the presence of nuclei; next numerous granules made their appearance in the liquor sanguinis. In some parts of the field these granules, with the nucleated white blood corpuscles, were the only things visible; but in focussing more deeply, *i.e.*, nearer the ozone, the outline of the red blood corpuscles could be made out. This appearance is probably due to the fact that the red blood corpuscles, having a higher specific gravity than the white blood corpuscles and the liquor sanguinis, sink gradually, and hence we have next the objective of the microscope, a layer of liquor sanguinis containing a few white blood corpuscles, and the granules produced by the action of ozone. After being exposed for thirty minutes to the action of ozone, the outline of the red blood corpuscle could be made out, and the liquor sanguinis was not coloured to any appreciable extent.

With frog's blood, the first change observed was the gradual appearance of the nucleus in the red blood corpuscles; then the corpuscles lost their colour, and the nucleus became more distinct. After this the white blood corpuscles lost their granular appearance, and show nuclei. The outline of the white blood corpuscles could always be easily made out. The liquor sanguinis was not coloured, but granules, similar to those observed with human blood, made their appearance in it. After the prolonged action of ozonised air the coloured corpuscles seemed to shrink in size. No free nuclei were seen at any time, and at the expiration of half an hour's exposure to a slow stream of air highly charged with ozone, the outline of the nucleated but colourless red blood corpuscles could be made out.

I compared the effects of ozonised air with that produced by a weak solution of acetic acid (three drops in a tumbler of water), and find that with human blood the addition of a drop of such a solution produces decolorisation of the red blood corpuscles *at once*, the outline can only faintly be seen, and the liquor sanguinis is coloured. With frog's blood we have *at once*

nucleated colourless red blood corpuscles, a coloured liquor sanguinis, and nucleated white blood corpuscles. With ozone, the complete decolorisation of the red blood corpuscles is a slow process, requiring, I found, four or five minutes.

Ozonised air having then such a characteristic effect upon blood if brought into contact with it, I exposed a Guinea pig to its action for an hour in the air-tight chamber, all the conditions being similar to those in Experiments from I. to X. The same effects were produced upon the number of respirations. Having microscope slides, &c. ready, at the end of the hour, and when the animal was nearly dead to all appearances, I killed it by a blow upon the head, obtained a drop of blood, mixed it with a small quantity of normal saline solution, and examined it with a power of 600 diameters. *No change* of any kind was seen—the red blood corpuscles were straw-coloured—the white, irregular in form, and changing these forms—the liquor sanguinis colourless, and free from the appearance of granules beyond these normally present in blood. This result, considered along with the observation given in the Experiment V., viz., that the breathing of ozonised air produced no marked difference in the amount of ozone in such air, leads to the conclusion that *ozone does not enter the circulation at all.*

How, then, does the breathing of ozonised air or ozonised oxygen interfere with the elimination of CO_2? We have seen that death cannot have been produced by the mixture of ozone with air or oxygen, owing to its increased density, preventing the elimination of the carbonic acid; the evidence before us does not warrant us in supposing that the diminution in the amount of oxygen, due to the conversion of a portion of it into ozone, is the cause of death: nor can the condition of asphyxia be due to the ozone acting upon the blood and interfering with its power of liberating the CO_2 from combination; and lastly, the experiments of Redfern show that death is not due to closure of the glottis, as the result of a reflex action.

I think that it is very probable that the non-elimination of CO_2, and the consequent death from asphyxia, results from the ozone, by its oxidising power, altering the character of the wall of the air-cells; so that, wherever ozone comes into contact with the wall, diffusion of gases is no longer possible or is seriously

interfered with at that part. If the atmosphere breathed by the animal contains a sufficiently large amount of ozone, the whole of the epithelium lining the air-cells will be affected and death will rapidly occur from asphyxia: if the amount of ozone be smaller, a portion of the air-cells will be affected, or the whole of the air-cells may be acted upon so as only partially to prevent the process of diffusion. In either case, death will occur all the more rapidly if the air breathed by the animal contains an excess of CO_2, inasmuch as this excess will interfere with the elimination of CO_2. But where the amount of ozone, as in my experiments, is not sufficiently great to affect all or the majority of the air-cells, the animal may not die from asphyxia, because there are a sufficient number of unaffected air-cells to allow the process of respiration to be carried on. But death, in such cases, results from the oxidising power of the ozone causing inflammation of the lining membrane. Emphysema of a portion of the lungs may be produced, but this condition must not be regarded as a cause of death, but as an attempt to gain, by an increase of the air-cells, an increase of membrane through which the interchange of gases may take place. If the amount of ozone be still smaller, the animal may recover from the bronchitis, or it may escape the bronchitis altogether, the upper part of the respiratory wall only being affected. This occurred in several of my earlier experiments, in which the ozone was generated in a simpler apparatus and in much smaller quantities.

From the symptoms which I have observed, I am of opinion that the following conclusions regarding the effect of the respiration of ozonised air may be drawn:—

I. Ozone depresses the nervous system. This effect is probably a secondary one, and due to the excess of CO_2 in the blood.

II. Ozone diminishes the number of the normal respirations, and as a result of this diminishes, in force and frequency, the action of the heart.

III. That inhalation of ozonised air produces a diminution in the normal amount of carbonic acid eliminated, and in the amount of oxygen absorbed.

IV. That the diminution in the number of respirations, the

diminished action of the heart, and the diminution in the amount of CO_2 excreted, are probably caused by the ozone affecting the character of the pulmonary mucous membrane.

V. That the alteration of the pulmonary mucous membrane by ozone may be, if the ozone be present in large quantities, or if the air breathed by the animal contains a large excess of carbonic acid, sufficiently marked to produce death from asphyxia within an hour.

VI. If the proportion of ozone in the air be less, the alteration of the pulmonary mucous membrane may not cause death from asphyxia, but may cause death from bronchitis.

VII. That the inhalation of an atmosphere containing 1 part in 100 parts by weight of air, for an hour, will probably cause death from bronchitis.

VIII. That ozonised air brought into direct contact with blood, produces decolorisation of the red blood corpuscles, stops the amœboid movements of the white blood corpuscles, renders the nucleus of the corpuscle apparent, and causes the appearance of granules in the liquor sanguinis.

IX. That this change in the red blood corpuscles is probably due to the union of the ozone with the hæmoglobin, as a result of which a colourless compound is formed.

X. That there is no evidence that the respiration of ozonised air produces a diminution in the amount of ozone in the air; nor is there any evidence that, in the breathing of ozonised air, the ozone enters the circulation.

Do these experiments lend any support to Schönbein's view as to the causation of epidemics of catarrh by an excess of atmospheric ozone? I think that there can be no doubt but that, if the atmosphere contains a sufficiently large amount of ozone, catarrh will be produced; but inasmuch as the amount present normally in the atmosphere has not been accurately determined, it is impossible to say when the ozone is in excess. If Houzeau's estimate of the amount present in the air be a reliable one (1 part in 450,000), then I would expect that a very

large excess would be necessary in order to produce catarrhal symptoms; but if Richardson's estimate (1 part in 10,000) is to be relied upon, then it is quite possible, or even probable, that a slight increase in the amount may cause such symptoms. But until the amount of ozone present normally in the atmosphere has been satisfactorily and conclusively estimated, the experiments with artificially prepared ozone neither support nor oppose Schönbein's view. But they do show, I think, that the inhalation of ozonised air in pulmonary affections is a method of treatment which should be very carefully, if at all, employed. Personally I have, while performing these experiments with ozonised air, suffered from an obstinate inflammation of the mucous membrane of the nose—and yet, beyond breathing the air of a large room which contained the ozonised air escaping from the exit tube of the air-tight box, I have not been exposed to the action of ozone. The affection, however, I noticed, became much more aggravated and painful if I, as a test of the presence of ozone at the commencement of an experiment, sniffed, however gently, the air escaping from the exit tube.

And the experiments show, further, that the inhalation of ozonised air, having for its object the absorption of ozone into the blood, cannot, at present, be advocated, inasmuch as ozone is not absorbed, and cannot therefore be of service in increasing the oxidising power of the blood.

ON THE MODE OF PROPAGATION OF NERVOUS IMPULSES.

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Different hypotheses have been propounded at different times to explain the mode of propagation of nervous impulses. Those which meet with most acceptance at the present day are two in number. First, the *vibratory hypothesis*, as it may be called, according to which the impulse depends on the displacement or vibration of the nerve particles; second, the *chemical hypothesis*, by which the impulse is represented as the result of a series of chemical changes in the nerve particles. Professor Huxley holds the first view, and in an article "On Sensation and Sensiferous Organs," which appeared in the April number of the *Nineteenth Century*, he quotes a passage from Hartley's *Observations on Man*, as containing a concise exposition of this view. The passage is as follows:—"External objects impressed upon the senses occasion, first on the nerves on which they are impressed, and then on the brain, vibrations of the small, and as we may say, infinitesimal medullary particles. These vibrations are motion backwards and forwards of the small particles; of the same kind with the oscillations of pendulums and the tremblings of the particles of sounding bodies. They must be conceived to be exceeding short and small, so as not to have the least efficacy to disturb or move the whole bodies of the nerve or brain." Further on in this article, Professor Huxley says—"It is quite possible that the particular mode of motion of the object is reproduced in the sensorium, exactly as the diaphragm of the telephone reproduces the mode of motion taken up at its receiving end." This hypothesis, it must be admitted, is at first sight plausible, and without doubt serves to explain several phenomena observed during the active condition of the nervous system. But notwithstanding the support it has received, I am disposed to believe that the weight of evidence is decidedly in favour of the other—the chemical hypothesis; and I shall take the liberty of directing attention to a number of facts, which when considered with reference to the cumulative evidence they afford, go far,

in my opinion, to disprove the vibratory, and at the same time confirm the chemical hypothesis. What is meant by the latter hypothesis I shall forthwith proceed to explain, and shall subsequently state the facts which make for and against the respective hypotheses.

By the chemical hypothesis it is assumed that the stimulus, whether mechanical, thermal, or electrical, when applied to a nerve, excites a chemical change in its molecules or elementary particles, and that this change travels along the nerve-like fire along a piece of wood or a train of gunpowder. The nervous impulse or force is supposed to be produced by the chemical reaction between the nerve particles and the blood, just as heat is generated by the chemical reaction between the particles of wood and the oxygen of the atmospheric air; and the nervous impulse may be considered an expression of the chemical change in the nerve somewhat in the same manner as heat is an expression of the chemical change in the case of the wood or gunpowder. But let us see to what extent this hypothesis is supported by facts.

1. A slight elevation of the temperature of the nerve occurs during the conduction of an artificial stimulus. Schiff[1] and Oehl,[2] by means of the thermo-electric apparatus, noticed this increase of temperature in large nerves like the sciatic.[3] Now, it is difficult to account for a rise of temperature that could be detected on the vibratory hypothesis, or on the supposition that nerves are nothing more than mere conductors, like the wires of the electric telegraph.

2. Chemical changes take place in nerves when in a state of activity; these are probably of the same nature as those that have been discovered in muscle, but are much less in amount. It can be readily understood that it is very difficult to make satisfactory analyses of the nerves on account of their small size—hence, no doubt, the discordant results arrived at by different chemists. But the white substance of the brain, which is composed essentially of nervous filaments, has been carefully analysed, and has yielded tangible results. Ranke showed that

[1] *Archives de Physiologie*, vol. iii. p. 75, Paris, 1870.

[2] Quoted in Carpenter's *Physiology*, p. 612, 1876.

[3] Helmholtz and Heidenhain, however, it is but just to mention, were unable to detect it.

if the brains of pigeons were deprived of blood, they absorbed oxygen and gave out carbonic acid. Nerves, after prolonged action, are acid in reaction (the acid is lactic according to Ranke); whereas, nerves, in a state of repose, possess a neutral reaction. Urea and cholesterin also are said to appear in nerves after action. On the other hand, it must be acknowledged that some chemists have not found the chemical changes I have indicated; and Dr M. Foster, adopting their view, states that the chemical changes in nerve are insignificant, or have not been satisfactorily made out.[1] Now, on the vibratory hypothesis, it may be urged that these changes, comparatively small in amount according to some chemists, result from the waste of the nervous tissue consequent on the vibration of the nerve particles. But it is scarcely possible that the mere vibration of particles, either in nerve-cells or in the nerves themselves, should give rise to so much waste as is indicated by the chemical products formed; or that the brain should receive nearly one-sixth, by weight, of the entire blood of the body, and should cease to perform its functions the moment its vascular supply is cut off, if, as on this hypothesis, blood were only required by it to supply the deficiency created by the "wear and tear." Even Foster appears to take this view; for he says, "the actual amount of energy developed by a most powerful nervous impulse is exceedingly slight, and hence chemical changes insignificant in amount may be the cause of all the phenomena and yet remain too slight to be readily recognised."[2] Moreover, we can scarcely imagine that the potential part of a nerve should be constituted by so highly vitalised a product as protoplasm, which exhibits so great a readiness to undergo chemical change, if its sole function be merely to serve a mechanical purpose, such as the transmission of vibrations; for any other tissue might have been as suitably employed for such a purpose, since it has been shown that nerves are but indifferent conductors of electricity, and furthermore have not a greater conducting power than other moist animal textures.[3] Besides the fact that the chemical constituents of

[1] *Text Book of Physiology*, p. 48, 1878.
[2] *Op. cit.* p. 79.
[3] Müller's *Physiology*, translated by Baly, vol. i. p. 684, 1840.

nerves and nerve-cells are, qualitatively, almost the same, renders it more than probable that the nerves play some part in the generation of impulses.

3. The phenomena of electrotonus *appear* to favour the vibratory hypothesis. Cyon's law to explain the anelectrotonic and cathelectrotonic zones of Pflüger is based, indeed, on the assumption that the nerve molecules may exist in three states; first, a neutral state, their ordinary condition; second, a state of increased mobility (cathelectrotonus); and third, a state of diminished mobility (anelectrotonus). But Matteucci, Hermann, Onimus, Radcliffe, and others, have shown by experiments, which I need not describe, that all the phenomena of electrotonus may be explained on purely physical principles, by considering the nerves merely as conductors of electricity; and that the changes in conductivity and excitability which occur in a nerve in this condition depend either on the electrolytic action of the electric current on the nerve [in which case acid would be formed at the positive pole, where it would lower the excitability, and alkali at the negative pole, where it would raise the excitability (Onimus)], or on "an internal polarisation which appears at the border between the sheath and the contents of the nerve-tube" (Hermann).[1]

4. It has been ascertained that the excitability of a nerve when exhausted by a direct current can be restored more promptly by stimulation with the inverse current than by absolute repose, and *vice versa*. In the second place, it has been demonstrated that any nerve when exhausted by a direct current is still sensitive to the inverse one. The explanation of these phenomena, in terms of the vibratory hypothesis, is that the molecules are assisted in returning to their original or ordinary position by the action of the inverse current; but the supposition that the acid and alkali generated at the positive and negative poles, by the electrolytic action of the direct current, are neutralised respectively by the alkali and acid formed on a reversal of the current, would seem to afford a more satisfactory explanation.

5. Marked changes in the chemical composition of the nerves destroy their excitability. Strong alkalies and acids, &c.,

[1] *Human Physiology*, translated by Gamgee, p. 346, 1878.

abolish the excitability of a nerve, whilst dilute solution of chloride of sodium increases it. The chloride of sodium may possibly act by dissolving the albuminous product, allied to myosin, which is formed in the nerve during its active condition, and so help to prepare it for undergoing chemical changes anew.

6. The excitability of nerves is increased by heat, and diminished by cold. This is explicable on the chemical hypothesis, for heat promotes combustion; but herein is the vibratory hypothesis at fault, since heat diminishes, whilst cold increases the conductivity of metals.

7. Fatigue renders nerves less excitable, exhaustion being usually accompanied by a retardation of the impulse-wave. The excitability of nerves depends on the state of their nutrition; and this, again, on not only the quantity but the quality of the blood. These facts are more easily interpreted by the chemical than by the vibratory hypothesis.

8. All varieties of stimuli—mechanical, thermal, electrical—give rise to the *same kind* of nervous impulse. This fact alone renders it, on the one hand, highly improbable that the impulse is caused by the vibration of the particles, and on the other hand, probable, that it originates in chemical action.

9. Chemical combination can take place with sufficient celerity to account for the rate with which a nervous impulse travels along a nerve. The velocity of propagation of chemical action depends to a considerable extent, as Bunsen showed in the case of gases, on whether the combustible substances are pure or are mixed with less combustible bodies; for by judiciously combining them in different proportions in a series of experiments, Bunsen was able to reduce by degrees the rate with which ignition was propagated until he could follow it with the naked eye. He further, by means of a most ingenious method, determined the velocity with which the ignition of gases travelled.[1] He found that this velocity for pure hydrogen and oxygen was 34 metres (111 feet) per second—a velocity, it should be remarked, identical with the average velocity of the nervous impulse in the motor and sensory nerves of man as determined by Helmholtz. The analogy between the two modes of propa-

[1] *Philosophical Magazine*, vol. xxxiv. p. 492, 1867.

gation is certainly striking; but, of course, I do not intend to suggest that the chemical change in nerve is nothing more than a union of hydrogen and oxygen. I merely take it as an instance of the rapid propagation of chemical action; and I would call attention to the whole series of Bunsen's experiments as tending undoubtedly to throw considerable light on the manner in which chemical action may take place in nerve.

10. Lastly, a nervous impulse presents the essential character of increasing in intensity, in a motor nerve, in proportion to its progress along it. Thus if a stimulus be applied to the nerve at the point *a*, and again at the point *b*, the contraction of the muscle will be much greater in the former case than in the latter; in fact, the maximum of contraction, as Pflüger pointed out, corresponds to the maximum of distance from the muscle.[1] These results are observed as well in a nerve in connection with the spinal cord as in one whose connection with it has been severed; they cannot, therefore, be due to the mere section of the nerve.

Heidenhain, too, has shown that, in a nerve in connection with the spinal cord, "the amount of contraction of the muscle is at first large,—then becomes smaller, and finally increases somewhat again, as the stimulation is carried from the roots of the nerves to the muscular periphery."[2] To explain this phenomenon on the vibratory hypothesis seems to be impossible; for, if a nerve were merely a conductor like an iron wire, the impulse propagated along it should, owing to the resistance, which is of a frictional character, gradually diminish from its origin. Two views, however, have been advanced to account for this peculiar phenomenon. The first is, that a greater impulse is produced on stimulation of the proximal than of the distal

[1] Marey, as the result of his experiments, arrived at a different conclusion from Pflüger, but most physiologists are now convinced of the accuracy of Pflüger's experiments.

[2] Foster's *Physiology*, p. 71

portions of a nerve, because the former are the more excitable. The cause of this increased excitability is believed by some physiologists to be "the proximity of the central organ with which the nerve is connected";[1] by others, that "the structure of the nerve, and especially of its sheath, may be more delicate in those parts which are more protected, and that it consequently there more readily responds to impressions."[2] But the results in question do not follow stimulation of the proximal end only, so that the proximity of the central organ cannot be the true cause; and, though the structure of a nerve is most delicate at its origin and its termination, I think it has yet to be shown that its nerves, in their course, become gradually less delicate or their sheaths gradually thicker; yet this ought necessarily to be the case, else the cause assigned for the increased excitability cannot be the true one. Thus, in order that the latter explanation hold good, it would be requisite that the sheath of the nerve should, as shown in the diagram, increase in thickness from *a* to *c*; but if it does not, then *cæteris paribus*, a stimulus applied at *c* should give a greater result than when applied at *b*.

The second view regarding this phenomenon was given by Pflüger: it assumes that the impulse gains force in its descent along the nerve like an avalanche. This, however, is rather an illustration of the phenomenon than an explanation of its cause. The only objection to it appears to be that the "negative variation" probably diminishes its intensity as it passes along the nerve (Du Bois-Reymond); but the observations on this point have not been sufficiently numerous to entitle us to draw a general conclusion from them. It occurs to me that the explanation which is on the whole the most satisfactory is

[1] Hermann's *Physiology*, p. 344, 1878.

[2] Carpenter's *Physiology*, p. 612, 1876.

afforded by a consideration of the mode of propagation of the nervous impulse as assumed by the chemical hypothesis. We can imagine a nervous impulse, generated as the result of chemical change in the particles or in the cross-section of a nerve at the seat of stimulation; and, as it passes towards the muscle, becoming slightly increased at each cross-section of the nerve, owing to chemical action, the total addition made to the original impulse being in some degree proportional to the distance it has travelled along the nerve. We might illustrate this hypothesis by a chain of Daniell's cells or a thermo-pile, in which the cells and the junctions would each of them respectively correspond to a cross-section of a nerve undergoing chemical change; and as in this illustration the amount of electricity produced is, within certain limits, proportional to the number of cells or metallic combinations, so is the nervous impulse increased by an addition at each cross-section as it proceeds onwards. Another illustration—but this, like the others, is only an illustration—is presented by the burning of a piece of wood. The heat developed by the combustion of the first portion raises the temperature of the succeeding portions, so that they burn more rapidly—more vigorously, that is, they give out more energy when the fire reaches them.

Whether the nervous impulse is a force in some respects resembling electricity, generated by, but distinct from, chemical action, or whether it is merely altered chemical force, possessing no separate and independent existence, I do not pretend to say, though I am disposed to take the first view; but either conception may be held consistently with the chemical hypothesis of the propagation of nervous impulses.

NOTE.

Herbert Spencer, I may add, holds the chemical hypothesis in a somewhat modified form. He believes the chemical change in a nerve-cell to be of the nature *decomposition*, and the chemical change in a nerve to be of the nature of *isomeric transformation*. The first change, that of decomposition, he says, is "usually accompanied by a great dissipation of motion, whereas the

motion given out or taken up along with the other (the isomeric transformation) is relatively insignificant."[1] To this view, at least in so far as the motion of molecules is made to depend on chemical change, I do not think any serious objection can be raised; however, granting the existence of isomeric transformation as a factor in the production of nervous impulses, it seems highly probable, from what I have stated above, that chemical decomposition takes place in nerves as well as in nerve-cells. Chemical change in nervous matter will no doubt give rise to more or less molecular or vibratory movement of the nerve particles; accordingly, to a certain extent, the *chemical* hypothesis may be regarded as including the *vibratory* hypothesis. But this is far from being equivalent to affirming that a nervous impulse is propagated solely by vibration of molecules irrespective of chemical change except as the result of the waste of nervous tissue.

[1] *Principles of Psychology*, vol. i. p. 21, 1870.

NOTE ON LOGWOOD STAINING SOLUTION.

By EDMUND ALLEYNE COOK, Ph.D., F.C.S.[1]

IN most histological text books this colouring material is stated to be good in its results but uncertain in its action; and from the numbers of formulæ given for the preparation of the solution, it is evident that many experimenters have endeavoured, without apparent success, to hit upon a combination which would be satisfactory in all points. The chemical nature of the colouring material of logwood is fairly stable, and affords no reason for any uncertainty, and it appeared desirable to determine under what conditions the solution could be made to yield the best results.

The colouring material of logwood consists of two substances —hæmatoxylin and hæmatein, the one differing from the other by two equivalents of hydrogen. Hæmatoxylin, the colouring matter containing the larger amount of hydrogen, is soluble in alum solution, while the hæmatein is slightly, if at all so. The latter is of no use to the histologist for colouring animal tissues. Hæmatoxylin forms compounds with various metallic oxides, which are soluble in alum solution also; and if a tissue be stained with hæmatoxylin, or with hæmatoxylin and a metallic oxide, and immersed in an aqueous solution of alum, the colour will be all discharged from the tissue and taken up by the solution; and the solution of alum will thus take up fresh quantities of hæmatoxylin compound until it reaches a point of saturation beyond which it will take no more from tissues, but will, if over-saturated with it, give up the colouring matter freely to immersed animal material. Such a solution of hæmatoxylin, alum, and metallic oxide has a clear purple colour, becoming red on addition of acids. If alkaline earths, alumina, or hydrated earthy phosphates be suspended in it, they will absorb the colour, and the solution becomes purple. If the solution be treated with a very small percentage of a chromate, the purple will gradually be replaced by a yellowish-brown colour; or if a tissue which has been stained with alum-logwood solution be immersed in an

[1] From the Physiological Laboratory, University of Glasgow.

exceedingly dilute bichromate solution, the purple will sooner or later be replaced by the yellow tint. If a section of any abnormal caseous concretion or abnormal growth be immersed in a neutral solution of alum-logwood, it will become of a more bluish purple than ordinary tissue, evidently from the presence in it of more than an ordinary amount of alkaline earthy matter or phosphate.

When the above facts are taken into consideration, it will appear unreasonable to expect tissues hardened in chromic solutions of any kind to colour as readily with an ordinary logwood solution as they would do if immersed in the fresh state, notwithstanding the assertion of any experimenters to the contrary. Sections of chromic-hardened tissues are exceptionally difficult to free from chromic compounds, most probably because part of the chromic acid is in chemical combination and insoluble, and when freed from the hardening material the tissues will not be left in the natural neutral state, and thus less readily will the nuclei take up the colour. But it has been found that hardened tissues if cut into sections and well washed, may be as readily stained with logwood as fresh tissues if the solution be slightly modified.

It has been found that the cheapest and most practical logwood solution may be made as follows:—

Take Logwood extract,	6	parts.
Alum,	6	„
Sulphate of copper,	1	„
Water,	40	„

All ingredients must be free from iron.

Grind the alum, logwood extract, and sulphate of copper in a mortar, and when powdered add sufficient water to form a thin paste; leave for one or two days, with occasional stirring, and then filter. The hæmatein contained in the logwood extract will be retained by the filter with the dirt, and the solution consists of hæmatoxylin, alum, and sulphate of copper, to which a crystal of thymol may be added to preserve it from mould. Fresh or alcohol-hardened tissues may be stained with this after sufficient dilution; but for chromic-hardened tissues, dilute 8 drops with 120 drops of water, and add 1 drop of $\frac{1}{10}$ per cent. solution of bichromate of potash just prior to use. Wash the stained

solutions in water as usual. *N.B.*—A larger proportion of bichromate solution will produce an ugly yellow; and if the mixed solution be kept many hours, some decomposition will go on.

Tissues stained in logwood may be mounted in glycerine or Farrant's solution or in dammar. In the two former they keep unchanged for any length of time, in the latter they are apt to fade unless care be taken, in preparing them for dammar, that the sections be thoroughly freed from water by absolute alcohol before being brought into contact with oil of cloves. If any moisture be left, fading will soon commence, and the preparation be spoiled.

CASE OF DEVELOPMENT OF HAIR ON THE EYE-BALL OF A DOG. By G. E. Dobson, M.A., M.B., &c.

A remarkable case of development of the hair, resembling in all respects that of the ordinary integument, on the eye-ball of a dog has lately come under my notice, and as I cannot find that a similar condition has been previously described, I proceed to give an account of this striking abnormality, which clearly demonstrates the correctness of the views of embryologists with regard to the homology of one at least of the structures entering into the formation of the organ of vision.

Lately, while on a voyage to Ceylon, I observed on board the ship a dog—a kind of mongrel bull-terrier—which appeared to be suffering some obstruction of the lachrymal duct, as the side of his face was kept constantly moistened by the overflowing tears. The owner of the dog, however, informed me that this condition was due to the presence of a wart on the eye-ball, which had always been there.

Having placed the dog under chloroform, I was enabled to examine the eye with facility. I found that a portion of the outer surface of the right eye-ball—triangular in outline, having its base along the margin of the cornea, and its apex near the external canthus—was occupied by hair-clothed skin, perfectly similar in all respects to the external integument covering the dog's face and body, the hairs being also quite similar in length, and even in colour, to those on the cheek of the animal. The extent of the hair-covered patch corresponded to the angular space left uncovered when the eyelids were normally open, and the hairs, which were equal in length, and densely set, ended abruptly, so that it appeared as if a portion of the outer integument, with hair attached, had been very carefully grafted upon the eye-ball. Owing to these hairs projecting beyond the eyelids, the latter could not be accurately closed, and during sleep these hairs being pressed between the lids conducted the tears outwards upon the cheek, causing the fur on that side to appear of a darker colour, owing to the constant state of moisture it was maintained in. A careful examination showed that the sclerotic, though perfectly developed all round this triangular patch, was evidently rudimentary, or very thin beneath it, and I was convinced that any attempt to remove the patch would be followed inevitably by protrusion of the contents or the eye-ball. In all other respects the eye was normal, the external canthus perfectly formed, and the eye-lashes as well developed as in the other eye.

Here then we have a most interesting demonstration of the homology of the conjunctiva with the integument of the body, showing how correctly the true relations of this structure have been worked out by embryologists. It is also worth noting, that in the same animal, though full grown, the testes had not descended, and there was no trace of a scrotal sac—another instance of arrested development.

NOTE ON GIACOMINI'S METHOD OF PRESERVING THE BRAIN. By Dr Osler, Montreal.

I have employed this method (see Prof. Turner's report in this *Journal*, vol. xiii. p. 282) with the greatest success, and can strongly recommend it to all who wish to prepare brains for demonstrative or museum purposes. After varnishing they look like beautiful wax casts, and when I demonstrated the specimens at the Medico-Chirurgical Society of this city, many of the members could scarcely believe that they were not artificial models. With the convolutions labelled on the one side, and Ferrier's centres mapped on the other, they make fine museum specimens—just fitting under the 7½ inch glass shades. Such cortical lesions as superficial spots of softening show remarkably well by this method.

In the details of the process I have accurately followed the directions above referred to, though, where the organ is perfectly fresh and firm, I think it better to remove the pia mater at once, and not wait for forty-eight hours as recommended. The glycerine should be good, otherwise the convolutions lose colour.

Anatomical Notices.

THE MORPHOLOGY OF THE OLFACTORY ORGANS.

Mr A. Milnes Marshall, Fellow of St John's College, Cambridge, gives, in the *Quarterly Journal of Microscopical Science*, his researches on this subject in the dog-fish, trout, salmon, axolott, frog, lizard, and chick. He finds that the olfactory nerves are solid, and agree completely in histological characters with the other cranial nerves; they appear very early, and are at first connected with the fore-brain, and not with the cerebral hemispheres; they arise like the other cranial nerves, except the optic sixth and fourth (?) from the upper part of the fore-brain, from the *neural crest*, *i.e.*, the *crest* formed by the fusion of the two neural *ridges* which grow out from the re-entering angles between the external epiblast and the neural canal, and from which the nerves, whether cranial or spinal, arise. Subsequently the upward and forward growth of the hemispheres drives the olfactory nerves down to the base of the brain, and so causes these nerves to appear to arise from their under and fore part. The connection of the olfactory nerves with the epithelium of the olfactory pit is acquired at a very early date. An olfactory lobe, when present at all, does not appear till an exceedingly late period of development. On this last point Mr Marshall shows that Remak's later statements are in accordance with his own, but have been overlooked by most recent writers, who have continued to repeat the earlier and incorrect statements of that eminent embryologist respecting the development of the olfactory vesicle.

The segmental value of the olfactory nerve, and its relation to the cerebral and skeletal segments, are discussed at much length. The segments of the brain are—1. The hind-brain, from the first vesicle of which the fifth nerve arises; from the second vesicle the facial (of which the auditory is regarded as a specialised branch); and further back arise the glosso-pharyngeal and the successive branches of the vagus. From the mid-brain arises the third or oculo-motor nerve. All these segmental nerves agree in the following characters:—(1) They appear early; (2) they arise from the neural crest, or the mid-dorsal surface of the brain; (3) they soon are shifted downwards to the sides of the brain; (4) they present, at least in their early stages, ganglionic enlargements, on or close to their roots of origin; (5) their course is at right angles to the longitudinal axis of the head; (6) they have definite relations to the segments of the head, as indicated by each nerve supplying two sides of a visceral cleft. To these tests the fourth and sixth nerves do not correspond, and they cannot be regarded as segmental, also the optic, though this may turn out to have segmental value. The olfactory nerve appears to answer to them all,

and is therefore regarded as the nerve of the fore-brain. The olfactory lobe, from its later appearance, the varying periods of its appearance, and its having no relation to the original position of the nerve, may be viewed rather as adult or adaptative than as an embryonic or primitive structure.

With regard to the relation of the olfactory nerve to the skeletal segments and visceral clefts, Mr Marshall gives reasons for thinking that the olfactory pit is really one of the foremost of the visceral clefts. It is in series with and parallel to the others; and the very close resemblance as to form, structure, general relations, &c., during the stages of development, and the time of appearance existing between the olfactory organ and the gill clefts, are sufficient to raise a strong probability that they are homologous structures. Not only do the Schneiderian folds and the gills appear at the same time, and agree completely in structure, but in no other part of the body do similar structures occur at any period. The conclusions are — *that the olfactory organ is the most anterior visceral cleft; that the olfactory nerve is the segmental nerve supplying the two sides of that cleft in a manner precisely similar to that in which the hinder clefts are supplied by their respective nerves; and that the Schneiderian folds are the homologues of gills.*

As to the clefts, the most anterior is the olfactory; next to that, following Parker, is the lachrymal, in front of the maxillary arch, to which the third nerve is related; next, the buccal or mouth cleft, between the maxillary and mandibular arches, to which the fifth nerve is related; behind this is the hyomandibular or spiracular cleft, supplied by the facial nerve; and, then, the branchial clefts supplied by the glosso-pharyngeal and by the several branches of the vagus.

The question is next discussed whether the visceral clefts are to be viewed as *intersegmental, i.e.*, as corresponding to the lines of separation of the original segments by the fusion of which we suppose the vertebrate head to have been formed; or as *intrasegmental, i.e.*, as apertures formed in the substance of the segments. The disposition of the segmental nerves, each supplying two visceral arches and only one cleft and certain other considerations, incline the author to the latter view, which is in opposition to the commonly received opinion; and this view acquires some additional interest in connection with Dr Dohrn's suggestion that the visceral clefts are the homologues of the segmental organs. The segmentations of the visceral clefts are produced not by segmentation of the mesoblast, but by the growth of diverticula from the alimentary canal; and such diverticula in invertebrates are rather segmental than intersegmental.

The *trabeculæ cranii*, running parallel to the longitudinal axis of the head, and at right angles to the segmental nerves and structures, must be regarded as axial structures, and not as arches. The labial cartilages grouped round the external aperture of the olfactory organ, like those in connection with the gape of the mouth, appear, as suggested by Parker, to be the homologues of the extra-branchial cartilages.

The various arguments adduced in favour of these views are, the author thinks, sufficient to outweigh the objection that may be raised from the fact that olfactory organs are involutions of the external epiblast, while the visceral clefts are formed by diverticula of the hypoblast of the foregut. Moreover, slight ingrowths of the epiblast towards the hypoblastic outgrowths of the pharynx may occur; and it is still a matter of uncertainty whether some of the gills are not epiblastic rather than hypoblastic. The position of the olfactory organ in front of the oral aperture, which might seem to be inconsistent with its being a gill slit, is probably due, firstly, to the hypertrophy of the fore part of the head carrying the olfactory sacs forwards; and, secondly, to an actual shifting backwards of the median element of the mouth.

THE PLACENTA IN THE SLOTH.

M. N. Joly has recorded in the *Comptes Rendus de l'Academie des Sciences*, 12th August 1878, his investigations on the placenta of *Bradypus tridactylus*, and has discussed the question of its classification. He had accidentally come into possession of a specimen of the fœtus and its membranes, but he does not say whether in the fresh condition, or after preservation in spirits. He describes the placenta as constituted by the amnion and chorion, and furnished on almost the whole of its external surface with a great number—more than a hundred—of lobules or cotyledons, of a more or less irregular figure, and varying in dimensions from 1 mm. to 1 or 2 cm.

Looked at on their outer face, the cotyledons were in some instances shaped like nummulites, others had the form and size of grains of millet; but those of largest size were like the multilobed kidneys of birds or of certain ophidians. Some more or less spacious cavities, in which were doubtless inserted the vessels of the hypertrophied mucous membrane, were to be seen on the outer face of the fœtal placenta. On the inner face the lobules formed numerous circumscribed swellings, often more than one cm. thick, adhering strongly to the chorion by their base, but for the most part free in the rest of their extent, and generally encompassed by the principal ramifications of the vessels which pass into their interior. M. Joly then refers to the often-quoted notice by Carus, who compared the placenta of the sloth to that of the Ruminants, and points out that in the sloth the lobes are contiguous, and not isolated and separated from each other like the cotyledons of a cow or sheep. He then proceeds to compare the placenta of *Bradypus* with that of *Propithecus* described by M. A. Milne Edwards. In *Bradypus*, he says, as in *Propithecus*, the chorion is almost entirely covered by compactly arranged villi, and resulting from the confluence of a number of irregular cotyledons, and that the lobes of the placenta diminish in number and thickness in proximity to the cephalic pole;

the two, in his opinion, so closely resembling each other as to lead to the conclusion that the sloth is a Lemurian and not an Edentate.

M. Joly makes no reference to and is apparently unacquainted with the memoirs by Professor Turner on the Placentation of the Sloths, in the *Trans. Roy. Soc. Edinburgh*, 1873, and on the Placentation of the Lemurs, in the *Trans. Roy. Soc. London*, 1876. Had he been so, he would have seen that the placentæ in these animals differ from each other in many most important particulars. The specimen which he had for examination was obviously a separated placenta, and as such was not in a condition to give him a full conception of the structure of the organ. He had apparently satisfied himself with a naked-eye examination of the placenta, for he makes no mention of having submitted it to microscopic examination. On the other hand, the specimen from a two-toed sloth, *Cholopus Hoffmanni*, examined by Professor Turner, quite fresh and attached to the uterus, was subjected to a minute microscopic examination both of the fœtal and maternal portions of the placenta. The conclusion which the latter anatomist arrived at was that the placenta in the sloths was dome-shaped and deciduate, and built up of many closely aggregated discoid lobes. In *Propithecus* and the Lemurs, on the other hand, the placenta is non-deciduate and diffused. In the special arrangements of some of the other organs, however, affinities do undoubtedly exist between the Sloths and the Lemurs.

M. Joly makes no mention of the membrane enveloping the fœtus, called by Welcker epitrichium, described by that anatomist and by Turner.

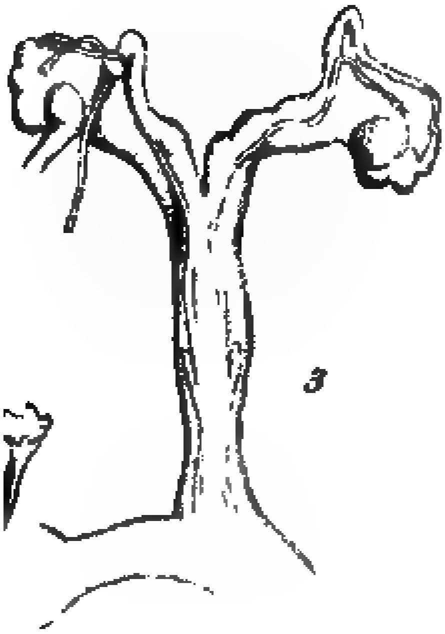
G. A. Gibson, del^{t} ad Photo

Hall & English, Lith^{s} Birm^{m}

Wm Allen MD, Auto. Lith.

C. Berjeau, lith.

Plate III



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Journal of Anat & Phys. Vol XIV.

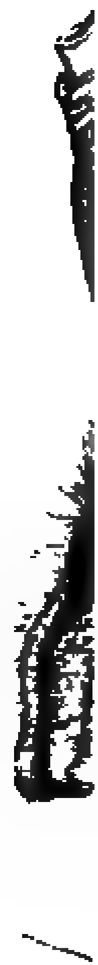

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Plate IV

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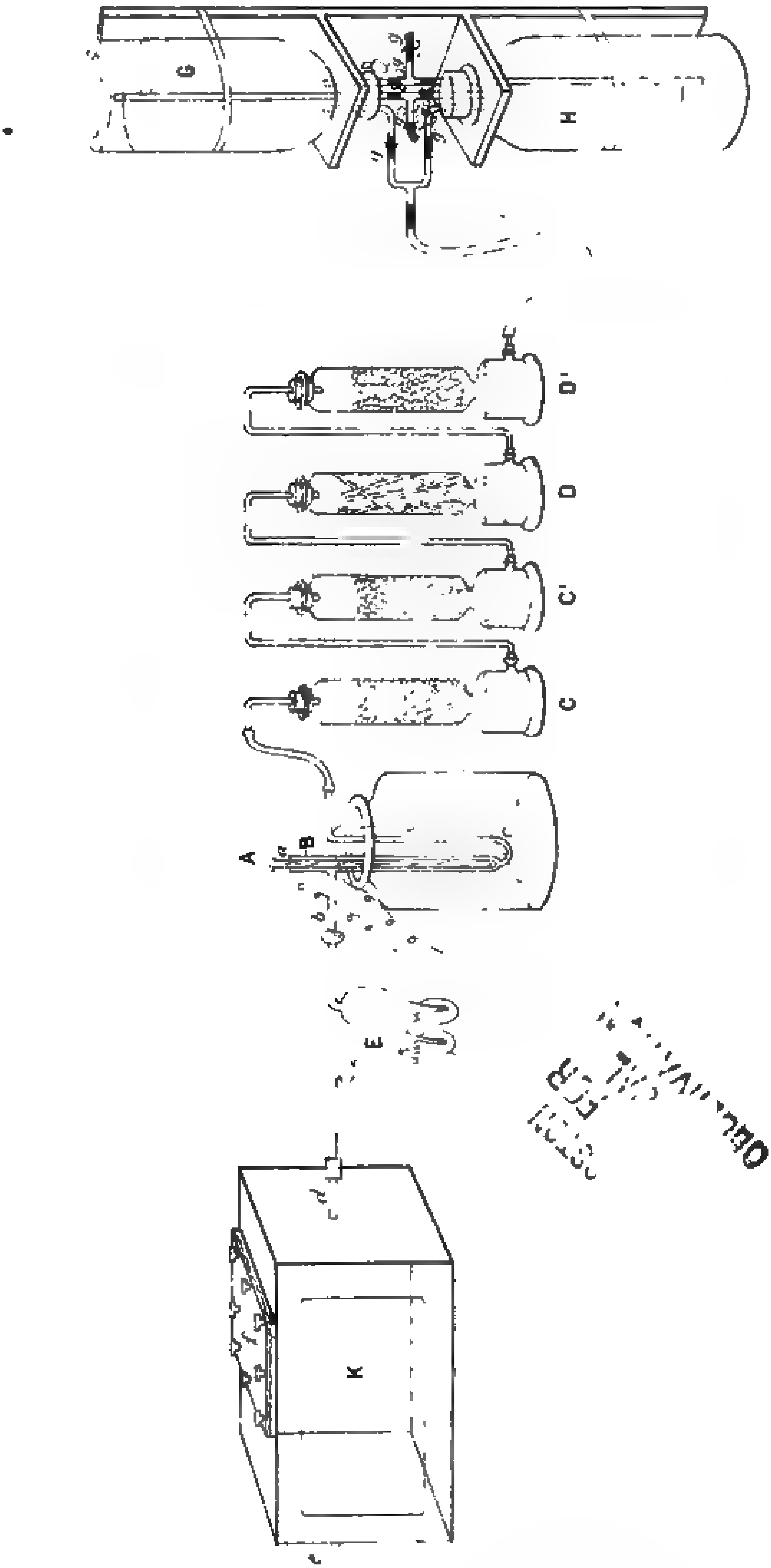

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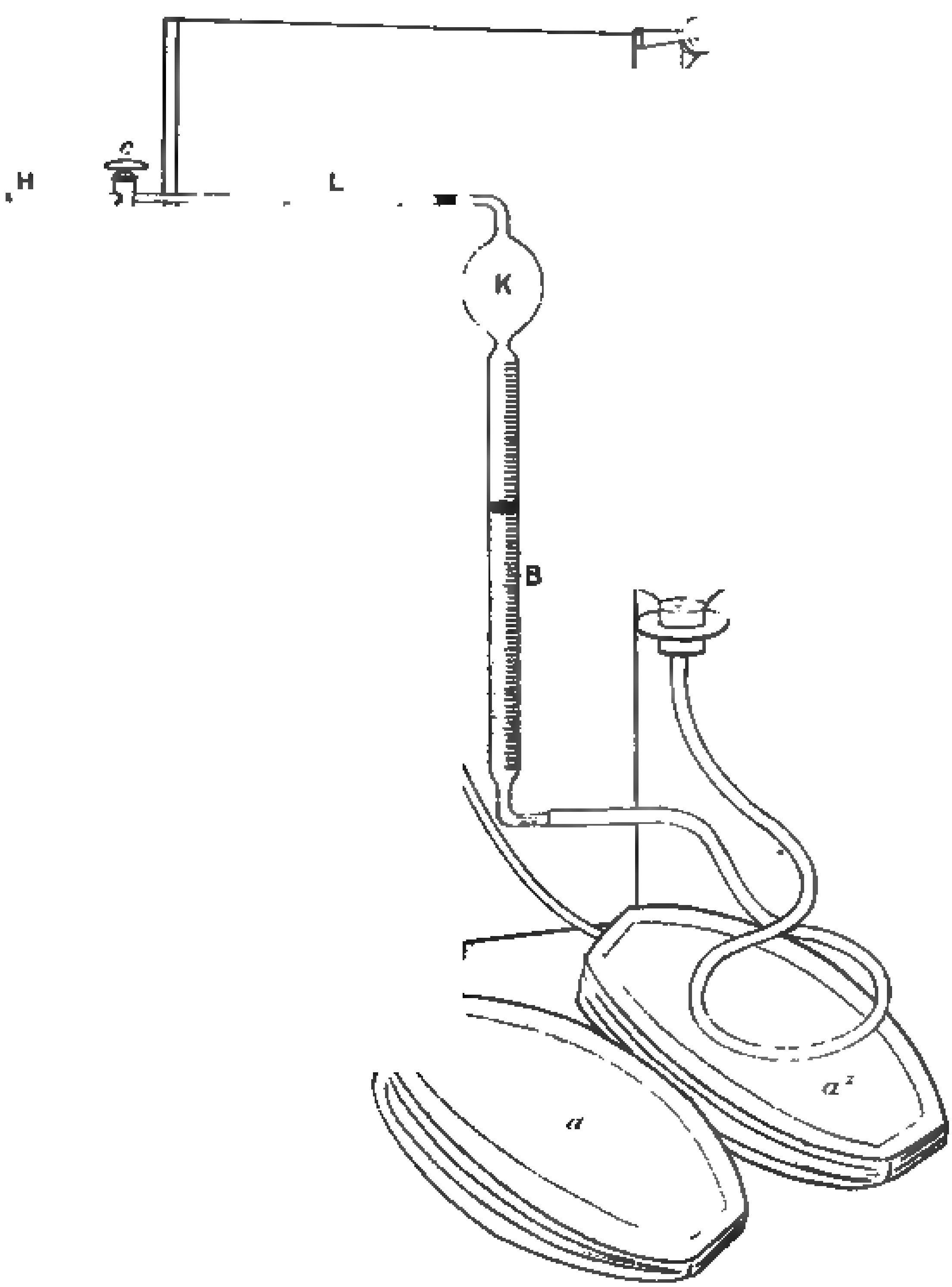
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Journal of Anatomy and Physiology.

THE INTRINSIC MUSCLES OF THE MARSUPIAL HAND. By ALFRED H. YOUNG, M.B., *late Assistant Lecturer on Anatomy, The Owens College, Manchester.* (PLATE VII.)

THE intrinsic muscles met with in the marsupial hand have recently been invested with more than ordinary interest, from the fact that, by reason of their peculiar disposition in the Thylacine, Cuscus, and Phascogale into definite layers or groups, they have suggested an actual type of arrangement to which the similar structures both in the hand and foot of all mammals are said to conform,[1] deviations from it being ascribed "either to suppression or fusion of certain of the elements of the different layers." Such a generalisation must necessarily be rendered more valuable by the augmentation of evidence upon which it is founded, hence I have thought a description of the hand muscles in marsupials, other than the above mentioned, would not be without interest and value, and this more especially, seeing that in three of the animals referred to,—viz., the Opossum, the Wallaby, and the Yellow-footed Rock Kangaroo,—the very symmetrical character of the manus promised a close adherence to a definite type.

The animals selected for dissection included the Opossum (*Didelphys virginiana*), Wallaby (*Halmaturus ualabatus*), Yellow-footed Rock Kangaroo (*Petrogale xanthopus*), Wombat

[1] D. J. Cunningham, "The Intrinsic Muscles of the Hand of the Thylacine, Cuscus, and Phascogale," *Journ. of Anat. and Phys.* vol. xii. p. 434. "The Intrinsic Muscles of the Mammalian Foot," *Journ. of Anat. and Phys.* vol. xiii. p. 1.

(*Phascolomys wombat*), and the Koala (*Phascolarctos cinereus*). For the opportunity of examining the three first named, I am indebted to Mr R. E. Holding; the remaining specimens are from the stores of the Owens College.

Before proceeding to a description of the muscles in question, it may be advisable to briefly recapitulate the leading features of their so-called typical arrangement; these will be found *in extenso* embodied in the highly interesting and suggestive papers by Dr D. J. Cunningham, to which reference has already been made. Basing his classification no less on anatomical than on physiological considerations, Dr Cunningham deems the intrinsic muscles of the hand and foot to be disposed in three layers—

1. A *plantar* layer of "*adductores*,"
2. An *intermediate* layer of "*flexores breves*,"
3. A *dorsal* layer of "*abductores*,"

these being arranged in three more or less well-defined planes, differentiated from each other both by position and function.

So far as the marsupial manus is concerned, my observations tend to confirm this view, therefore the following descriptive accounts are given in accordance with it. At the same time, whilst adopting for convenience this mode of description because of its suitableness to the special instances to which I shall have to refer, I do not wish to be understood as attributing to it any "typical" importance, either with respect to the Mammalia generally, or more particularly even to the group of marsupials themselves.

Opossum.

The hand of the Opossum is so bilaterally symmetrical, and the trilaminar arrangement of the intrinsic muscles so definite and well-marked, that it seemed advisable to supplement the description of these muscles by illustrative sketches of the different groups. (See Plate VII. figs. 1, 2, and 3).

Palmar Group. (Fig. 1.)

Four adductor muscles are comprised under this heading, they are distributed respectively to the two outer and the two inner digits, and therefore consist of—(1) an *adductor pollicis;* (2)

an *adductor indicis;* (3) an *adductor annularis;* and (4) an *adductor minimi digiti.* All arise from a mesial tendinous raphe, situated in the region of the palm, which extends from the carpal ligaments down to the distal extremity of the third metacarpal bone. The adductor pollicis and the adductor minimi digiti, both triangular in shape, are large, thin, and flat muscles, of almost equal size; they arise from the whole length of the mesial raphæ, and are inserted by their apices, the former into the base of the first phalanx of the thumb, on its ulnar side, the latter into the radial side of the first phalanx of the fifth digit. On a deeper plane, and indeed almost concealed by the foregoing, are the two remaining adductors, viz., those of the index and ring fingers respectively. Very small and feeble, they are not easily separable from the intermediate group of muscles. Both arise, one opposite the other, from the lower half of the raphæ previously referred to, and pass to the adjacent sides of their respective digits. The condition of the two last muscles is noteworthy, as indicating a tendency to disappearance, possibly by fusion with the flexor group.

Intermediate Group. (Fig. 2.)

This group, concealed in great part by the palmar layer, is constituted by a series of ten muscular bundles, arranged in pairs, which are situated on the palmar aspect of the five metacarpal bones, each digit possessing its special flexor brevis. The muscles are quite distinct from the dorsal group.

The *flexor brevis pollicis* is the smallest of the group; its two muscular bellies arise in common from the distal row of the carpus, and are inserted into the base of the first phalanx of the thumb, one upon either side.

Flexor brevis minimi digiti is somewhat stronger than the flexor pollicis; its ulnar belly arises from the unciform hook, whilst that more radial in position springs from the base of the fifth metacarpal bone, as well as from the adjoining ligaments. The insertion of each belly is into the corresponding side of the base of the first phalanx of the little finger.

The rest of the flexor group, distributed to the three middle digits, are much stronger muscles than the foregoing. More particularly does this apply to those of the index and ring

fingers. All arise from the proximal extremities of the metacarpal bones, whilst, in addition, some of the bellies have also an origin from the mesial tendinous raphæ of the palm; thus the *flexor brevis medius* possesses such an additional attachment; so also the adjoining bellies of the flexors of the second and fourth digits; the latter spring from the superior half of the raphe and conceal the upper portion of the flexor medius. The insertions of the muscles are into the first phalanges of their own digits, as in the case of the thumb and little finger. Small sesamoid bones exist in connection with the insertions of all the flexors.

Dorsal Group. (Fig. 3.)

With the customary four dorsal interossei, this group also includes the abductors of the thumb and little finger, which, though palmar in position, and consequently not in the same plane as the interossei, are, however, associated with them by reason of their abducting action.

Abductor pollicis.—Small but distinct, this muscle arises from the trapezium, and also from a tongue-like cartilaginous prolongation from the tendon of the extensor ossis metacarpi pollicis. It is inserted into the radial side of the first phalanx of the thumb.

The *abductor minimi digiti* is considerably larger than the abductor pollicis. It arises from the unciform bone and from the annular ligament; it passes to the first phalanx of the outermost digit and is inserted on its ulnar side.

The *dorsal interossei*, four in number, appear when viewed from behind, to resemble closely the corresponding structures, as described by Dr Cunningham in the Thylacine.[1] That occupying the first interosseous space, viz., the *abductor indicis*, arises by a single head from the shaft of the first metacarpal bone, and is inserted into the radial side of the base of the first phalanx of the index finger. The remaining three muscles all possess double origins from the adjacent sides of the metacarpal bones, between which they are placed. The fibres derived from each bone form distinct muscular bellies, two of which occupy each intermetacarpal space. The two bellies terminate

[1] *Loc cit.* p. 437.

inferiorly in a single slender but well-defined tendon of a more or less arched character. In the case of the fourth or outermost interosseous muscle, this tendon is attached by one extremity to the distal end of the fifth metacarpal bone, and by the other to the adjoining side of the first phalanx of the ring finger, its main action being that of an abductor of this digit.

The inferior tendons of the second and third interossei are more curved; the extremities of the arched tendon are attached to the contiguous sides of the first phalanges of the middle and immediately adjoining digits. To a slight extent they are also connected with the extensor tendons.

The actions of the muscles last described are somewhat complex; certainly, as in the Thylacine, they approximate the three middle digits, but they may also act either as simple abductors of the middle digit, or adductors of the second and fourth respectively, thus compensating to some extent for the feebleness of the rudimentary true adductors of the index and ring fingers.

No *opponens pollicis* exists; there is, however, a well-developed *opponens minimi digiti* inserted into the ulnar side of the fifth metacarpal.

WALLABY.

In this animal a well-defined *palmaris brevis* is present. It arises in the centre of the palm, and passes outwards to the skin over the muscles of the little finger.

Palmar Group. (Fig. 4.)

The muscles of this layer are four in number—one for each digit, except the medius. The respective muscles are almost equal in size; each consists of a strong, rounded, muscular bundle, more or less divisible into a superficial and a deeper portion; slender, superficial, accessory slips are, moreover, to be found in connection with the two muscles most remote from the middle line of the hand. Presenting what appears to be the usual marsupial tendency for the middle line, the adductor muscles arise from the ligamentous structures on the palmar surface of the carpus, and also from a mesial tendinous raphe, situated along the palmar aspect of the middle metacarpal bone.

Their insertion is as follows—the two innermost into the ulnar sides of the first phalanges of the thumb and index finger respectively, the two outermost into corresponding parts of the ring and little fingers on their radial sides.

Dorsal Group.

The *abductor pollicis* and *abductor minimi digiti*, are both present, the latter being by far the strongest of the two. The *abductor pollicis* is a small muscle which springs from the annular ligament, and from the radial sesamoid bone. It is inserted into the radial side of the first phalanx of the thumb and the adjoining sesamoid, whilst a few of its deeper fibres, though quite inseparable from the rest, are inserted into the metacarpal bone, and represent an *opponens pollicis.*

The *abductor minimi digiti* is very powerful. It arises from the annular ligament anteriorly, and is inserted into the ulnar side of the first phalanx of the little finger and the adjoining sesamoid.

An *opponens minimi digiti*, quite distinct, arises from the unciform bone and annular ligament; it passes to the ulnar side of the fifth metacarpal shaft. Comparatively this is a large muscle.

The *dorsal interossei* (figs. 5 and 6) occupying the intermetacarpal spaces are four in number. In general arrangement and action they are very similar to the corresponding muscles in the Thylacine and Opossum, there are, however, certain differences which necessitate a special reference. Viewed dorsally the first and fourth are seen to be single-headed muscles, whilst the second and third are double-headed, and closely simulate in appearance the corresponding muscles in the human hand.

The first dorsal interosseous from the metacarpal of the pollex, possesses also a narrow additional slip of origin from the trapezium; it passes to the first phalanx of the index finger and adjoining sesamoid, forming therefore an *abductor indicis*; the fourth dorsal interosseous has similar attachments to the fifth metacarpal shaft, and to the ulnar side of first phalanx of the ring finger, constituting an *abductor annularis.*

The second and third dorsal interossei have a somewhat remarkable arrangement. On their dorsal aspect, as previously

stated, they closely resemble the corresponding structures in the human hand. They appear as bicipital muscles, springing from the contiguous surfaces of adjoining metacarpal bones; the fibres converge inferiorly to a common insertion, the plane of which is much more palmar in position than is that of origin. Turning next to the palmar aspect of the muscles, two additional bellies are found occupying each of the respective interosseous spaces. These are more or less separable from the bellies seen dorsally, so that four muscular bundles—two dorsal and two palmar—are distinguishable as constituting the third and fourth dorsal interosseous muscles. All end inferiorily on a common arched tendon which by its extremities is attached, as in the Opossum, but on a more anterior plane, reaching indeed as far as the sesamoids. In respect of action they agree with the Opossum and the Thylacine, whilst, by virtue of their palmar insertion, they possess also a slight flexor action.

Intermediate Group.

The flexores breves do not form a distinct intermediate layer; with two exceptions, they are, indeed, practically wanting, *i.e.*, as separate muscles.

The pollex is furnished with a flexor, of which the radial belly is isolated, whilst the ulnar can only be regarded as formed by the deeper part of the adductor pollicis; similarly, also, in the case of the little finger, where the radial half may be considered as composed by the deeper fibres of the adductor minimi digiti, whilst its ulnar belly is situated beneath the abductor minimi digiti, and is with difficulty separable from it. As to the remaining digits, the only representatives of the flexores are to be found in the deeper parts of the adductor muscles, or it may be that the palmar bellies of the dorsal interossei more truly represent them. If the latter view be adopted, however, then the flexors of the index and ring fingers, so far as regards the belly farthest from the middle line, must be considered as entirely suppressed, whilst in opposition to it is the circumstance, that similar accessory palmar fibres to the dorsal interossei muscles apparently coinciding with the palmar portions of the central interossei in the Wallaby, exist in the manus of the Thylacine, in

which animal there is also a distinct intermediate layer of "flexores breves."[1]

Yellow-footed Rock Kangaroo.

On dissecting the hand of this specimen, the peculiar arrangement of the *lumbricales* attracted my attention. Four in number, they arise, as in other marsupials, from the common tendon of the deep flexor, but in their distribution a deviation from what is usually found is to be noted. They are distributed to all the digits except the middle one, consequently the pollex is furnished with a lumbrical muscle.[2]

The intrinsic muscles closely correspond to those which have been described in the manus of the Wallaby, the intermediate group of muscles is perhaps even less differentiated from the dorsal than in the latter animal, whilst the accessory slips of the palmar layer are with difficulty distinguishable.

Wombat.

In this animal the manus is not quite so regular and symmetrical as in the case of the Opossum and Wallaby; the three layers of muscles are, however, more easily distinguishable, but the constituents of these layers are of a more irregular nature.

Palmar Group.

Four adductors arise from the ligamentous structures on the palmar aspect of the carpo-metacarpal articulations; there is the usual marsupial tendency of these muscles to seek a common central origin, which in the Wombat, however, is not mesial in position, but corresponds rather to the palmar surface of the index metacarpal shaft. Consequently the adductor pollicis is shorter and smaller than the others; these latter progressively increase in length and size as we pass to the ulnar side, the adductor minimi digiti being the largest of the group. The muscles form a particularly well-defined plane, and are distributed to the first, second, fourth, and fifth digits, in the usual manner.

[1] Dr Cunningham, *loc. cit.* p. 488.

[2] If this be not an individual peculiarity it affords an additional argument against Meckel's hypothesis, that the "flexores breves" were distinct repetitions of the lumbricals.—*Anatomie Comparée*, tome vi. p. 345.

Intermediate Group.

The flexores breves, taken generally, are small. As a rule two muscular bellies are associated with each digit. These, however, are very unequal in size, the ulnar belly being only one-third the size of that radially situated. In the case of the index finger, the radial belly has conversely disappeared, and does not exist, unless it be coalesced with the abductor indicis.

Flexor brevis pollicis consists of two bellies almost equal in size; the radial passes from annular ligament to corresponding side of first phalanx of thumb, the ulnar from ligaments at base of second metacarpal to corresponding side of same phalanx, blending also with the lateral expansion of the extensor tendon.

The *flexor brevis minimi digiti* is strong; its ulnar moiety is from the unciform hook to the ulnar side of the first phalanx; the radial belly springs from the ligamentous structures at the carpal extremities of the metacarpals; it corresponds in extent and lies under cover of the adductor minimi digiti, and is inserted with it. Crossing the palm somewhat obliquely it conceals in part the ulnar belly of the flexor annularis.

The remaining flexor bundles arise from the palmar aspect of the metacarpals near the carpal ends, and pass to be inserted partly into phalanges of respective fingers, blending also with the terminations of the dorsal interossei. Small sesamoids are connected with the insertions of these muscles.

Dorsal Group.

This group includes the *abductor pollicis*, the *abductor minimi digiti*, and the *dorsal interossei;* the two former are arranged much as are the same muscles in the Opossum. There is no opponens either of the thumb or little finger.

Of the dorsal interossei there are but three, that usually constituting the abductor annularis, *i.e.*, the fourth, being entirely wanting.

The three dorsal interossei, very strong and well-developed, occupy the three radial intermetacarpal spaces; they are arranged exactly as in the Opossum, the abductor indicis, however, being, like the remaining two interossei, a bicipital muscle, as in the

human hand. By their insertions they join the expansions of the extensor tendons.

The absence of the fourth or outermost interosseous muscle has been already affirmed; its place is taken by a well-defined tendinous offset from the tendon of the extensor minimi digiti; this passes to the fourth digit, to be inserted like the interossei. The extensor minimi digiti consequently acts also as the abductor of the ring finger.

Koala.

I shall not include here a lengthy description of the hand muscles of the Koala, but content myself with the brief statement, that in their arrangement they agree fundamentally with those of the other species already referred to. There is, however, one point in connection with the intrinsic muscles of the manus in the Koala to which I wish to direct attention. The digits in the fore limb of this animal are characterised by the peculiarity of their disposition. They form two groups, of which one, including the thumb and index finger, is opposable to the other, this latter comprising the three remaining digits.

The index digit, in point of fact, constitutes a second thumb, and in conformity with its unusual freedom of action, its special muscles are well developed. Moreover, as a result of the arrangement of the digits into two groups, the middle line of the hand no longer passes through the third digit, but along the fourth; the muscles of the hand are correspondingly modified, and hence, so far as regards their insertions, the arrangement is very different to what is ordinarily found. The abductors and adductors act as usual from or to a middle line, but this, in the case of the Koala, passes along the fourth digit.

Concluding Remarks.

It is evident that, with respect to the disposition of the intrinsic muscles of the hand and foot, a considerable number of marsupials agree closely with what has been laid down as the actual "type" upon which these muscles are arranged in the whole of the Mammalia. But it does not appear that this "type" is so constantly adhered to in any other group of the Mammalia; on the contrary, the deviations from it are so numerous and of

such a nature as to render the justifiability of its extension to all mammals questionable.

It is true that examples of an arrangement of these muscles, more or less perfect in its accordance with the type set up, have been pointed out by Dr Cunningham[1] in the feet of certain mammals other than marsupials; to such it will presently be convenient to refer at greater length. Further, Dr Cunningham is supported by the authority of Professor Humphry,[2] who, in his observations regarding the "Myology of Orycteropus Capensis," expresses the opinion that a threefold division of the muscles in connection with the digits is the "typical" arrangement.

Nevertheless, that it is among the marsupials as a class that we find the "typical arrangement" most closely adhered to, may, so far as present observations extend, be taken as granted.

But it is to be observed, that even among marsupials there are many instances of a deviation from the "type," *e.g.*, it will be readily seen, on referring to the descriptions of the few specimens noted in this paper, that whilst the Wombat and the Opossum, in the disposition of their intrinsic hand-muscles, agree in all respects with the requirements of the "typical arrangements," the Wallaby and the Yellow-footed Rock Kangaroo deviate from the type set up, inasmuch as in these animals there is no distinct intermediate layer. Whether the absence of this latter in the animals last mentioned is attributable to fusion of its constituents with the palmar layer—as certainly seems to be the case in part—or whether the palmar bellies of the second and third dorsal interossei should not rather be regarded as properly belonging to the intermediate series, I am not able to determine, and at the same time I have to regret my inability to avail myself of any light which the distribution of the nerves might throw upon the problem.

Whether in the Wallaby and the Yellow-footed Rock Kangaroo we have a condition representing the appearance, or conversely the disappearance, of a trilaminar differentiation of the intrinsic hand-muscles, can only be determined by more extended observations.

[1] *Journ. of Anat. and Phys.* vol. xiii. p. 7, *et seq.*
[2] *Ibid.* May 1868, vol. ii.

Seeing then that even marsupials differ as to the extent of their conformity with the typical arrangement, it becomes of considerable interest to note what species are most perfect in their agreement with the type, what species deviate from it, and further, to consider to what cause the differences in these respects are attributable.

As regards the first points, it may be briefly stated that, so far as one is entitled to arrive at any conclusion from a consideration of the species already examined, with hardly an exception the intrinsic muscles are found to be most perfectly in accordance with their so-called "typical arrangement" in those marsupials in which, from their general habits and modes of life, a more than ordinary development and differentiation of the muscles might naturally be expected. Take, for example, the Cuscus, the Phascogale, the Opossum, the Koala, and the Vulpine phalanger. These all possess considerable skill in climbing, some indeed pass almost an exclusively arboreal existence; the hands and feet therefore are constantly employed in grasping. The Wombat, on the other hand, though terrestrial in its habits, frequently uses its strong claws for digging and burrowing purposes, for which reason, indeed, it is commonly known among the colonists as the "Badger." To accomplish such acts as these, it is quite evident not only that the digits, in consequence of their constant use, acquire a certain degree of independence, but also that some provision for maintaining a continuous and powerful flexion of the digits, without at the same time interfering with the free movements (especially those of extension and dorsiflexion) of the wrist is absolutely necessary; hence the differentiation and development of the "flexores breves" to supply the requirement. It is a fact worthy of note that in many cases where the short flexors are markedly differentiated as strong and distinct muscles, they are associated with a correspondingly weak and ill-developed flexor perforatus. So that, whilst the total flexing power is not necessarily altered to any material extent, a considerable portion is localised in the palm, and exercises no influence on the movements of the wrist joint.

I have pointed out what I believed to be the *raison d'etre* of the intermediate group of flexors in a manus characterised by the complete trilaminar arrangement of its intrinsic muscles.

For similar reasons those digits, in any manus which are endowed with the most independent powers, have invariably the most distinctly differentiated muscular arrangements; hence, even when the whole of the digits are supplied with the "typical" complement of muscles, the first and fifth are very commonly more favoured than the rest. This is well exemplified in the hand of the Koala. In this animal the index finger enjoys a peculiar independence, and, distinctly associated with this fact, we find the digit furnished with abductor, adductor, and flexor brevis, more markedly differentiated and more strongly developed than those of the remaining digits, with the exception of the pollex proper.

If we now consider the condition of the intrinsic muscles in the higher Mammalia, it is quite clear that the same remarks apply equally to them as to the marsupials, and amongst them the only two animals in which, so far as I am aware, the disposition of the muscles under consideration conforms entirely to the "typical" arrangement so frequently referred to—viz., the Otter and the Badger—are precisely those in which from their known habits we should expect to meet with it. That this is in no way to be associated with the pentadactylous nature of these animals is, I think, sufficiently evidenced by the arrangement of the intrinsic muscles in both the hand and foot of the closely-allied pentadactylous *Viverra civetta*, which, in respect of a less differentiated or specialised condition of these muscles, agrees rather with the tetradactylous carnivora.[1] It appears, therefore, that the development and differentiation of the intrinsic muscles of the hand and foot in all mammals is, most probably, directly dependent on use and requirements, and that the anatomical characters of these muscles, as with others, run parallel with their functional changes.

With these facts in view, can we regard the division of the intrinsic muscles into three layers disposed in the manner previously referred to as a "typical arrangement," in conformity with which the similar structures in all other mammals may fairly be said to be built up?

Whether it is advisable to come to any decision regarding the "typical arrangement" of a group of muscles from the considera-

[1] *Journ. of Anat. and Phys.* vol. xiv. p. 176.

fingers. All arise from the proximal extremities of the metacarpal bones, whilst, in addition, some of the bellies have also an origin from the mesial tendinous raphæ of the palm; thus the *flexor brevis medius* possesses such an additional attachment; so also the adjoining bellies of the flexors of the second and fourth digits; the latter spring from the superior half of the raphe and conceal the upper portion of the flexor medius. The insertions of the muscles are into the first phalanges of their own digits, as in the case of the thumb and little finger. Small sesamoid bones exist in connection with the insertions of all the flexors.

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With the customary four dorsal interossei, this group also includes the abductors of the thumb and little finger, which, though palmar in position, and consequently not in the same plane as the interossei, are, however, associated with them by reason of their abducting action.

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[1] *Loc cit.* p. 437.

inferiorly in a single slender but well-defined tendon of a more or less arched character. In the case of the fourth or outermost interosseous muscle, this tendon is attached by one extremity to the distal end of the fifth metacarpal bone, and by the other to the adjoining side of the first phalanx of the ring finger, its main action being that of an abductor of this digit.

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The actions of the muscles last described are somewhat complex; certainly, as in the Thylacine, they approximate the three middle digits, but they may also act either as simple abductors of the middle digit, or adductors of the second and fourth respectively, thus compensating to some extent for the feebleness of the rudimentary true adductors of the index and ring fingers.

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WALLABY.

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Palmar Group. (Fig. 4.)

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tion of comparatively few species, and these among the most highly-developed group of the vertebrates, without having regard to their primitive condition in more lowly organised forms, seems doubtful.

Certainly it is evident that before any definite answer can be given to the above question, we require not only much more extended observations as to the actual condition of these muscles in other mammalian and lower vertebrate forms, but above all we need definite knowledge of the various stages in the development of the muscles under consideration.

The history of the developmental changes indeed will afford the only sure data for the determination of that fundamental arrangement which alone can be considered as constituting an actual and inclusive "type," in contradistinction to one purely ideal or hypothetical.

The knowledge of the various developmental changes in a single species will not, however, prove sufficient for such a purpose, more especially if this again relates to one of the highest mammals, otherwise the careful and elaborate researches of Dr Ruge (Heidelberg) would to a large extent furnish the desired data. Dr Ruge's investigations as to the "Processes in the Development of the Muscles of the Human Foot"[1] are almost exhaustive. It is, however, to be regretted that the observations have not been rendered complete by a description of the derivation and development of the abductors of the first and fifth digits. With respect to the deeper muscles, it is pointed out that at a very early period the interossei are easily distinguishable as forming two layers—dorsal and plantar—the different elements of which are already discernible. The flexor brevis minimi digiti is also distinguishable, and is associated by Dr Ruge with the interossei, partly because of the similarity of its arrangement with the interossei found in lower animals, and in the early stage of man, and partly because the nerve supply is derived from the same source as that of the muscles of the fourth interosseus space. The muscles of the great toe are considered as a separate group. Disregarding this separation, at least for a time, it will be convenient to adopt the view commonly enter-

[1] *Morph. Jahr.* 1878, p. 117 *et seq.* *Note.*—The conditions described for the interossei in the foot, are essentially the same in the case of the hand (p. 125).

tained, and consider the abductors and adductors of the first as well as of the fifth digit as perfectly analogous to the interossei,[1] and associated with them. In some adult mammals—*e.g.*, the ornithorhynchus[2]—the whole series of intrinsic muscles may fairly be regarded as forming but two distinct layers; the precise functions of these may and do vary in accordance with special requirements; the deeper layer, for instance, is in some cases pre-eminently a "flexor" layer, in others an "abductor" or even an "extensor" layer.

It has yet to be shown in how many cases this condition is due either to the fusion of previously existing separate layers, or to the disappearance of one of these. That such may afford a probable explanation in certain instances, is evidenced by the condition of the muscles in the foot of the *Dasypus sexcinctus*,[3] but at the same time it is equally probable that in other instances the existence of only two layers is not attributable to the fusion or disappearance of a third layer, but may represent the original condition. In the latter cases, at least, the whole series of intrinsic muscles in the early embryo would probably present a precisely similar arrangement to that described by Ruge for the interossei in the hand and foot of the human embryo.

But further, whilst some animals permanently maintain a bilaminar condition, others may present a still greater divergence from the "trilaminar type," and the whole of the intrinsic muscles, as in the foot of the *Bathyergus capensis*, may be reduced to a single muscular layer; much more commonly, however, the bilaminar condition is exceeded, and this in varying degrees not only up to, but even beyond a trilaminar arrangement. When a third layer appears it is most frequently represented in connection with those digits which possess the greatest freedom in their actions, or those most used for grasping purposes, hence in many

[1] Meckel: *Anatomie Comparée*, vol. vi. p. 344.

[2] Meckel, *loc. cit.* vol. vi. p. 344; Ruge, *Morph. Jahr.* vol. iv. plate xxxv. fig. 46.

[3] In this animal the place of missing muscular elements is "taken by fibrous bands." (Cunningham, *loc. cit.* vol. xiii. p. 10). It is not so easy to explain the total absence of all the intrinsic muscles, with the exception of the "intermediate" group of "flexors," in the foot of the *Bathyergus capensis*. Here there is apparently no trace of the missing muscles. The flexores breves, however, are, according to Cunningham, strong and well developed (*loc. cit.* p. 11). Taking into consideration the habits of this animal it is of peculiar interest to note that the whole of the intrinsic muscles appear to be devoted to flexion of the digits.

cases the additional muscular elements are limited to the first, or first and fifth digits, as in man; in other cases again they extend to the remaining digits, so that a complete third muscular layer exists as in many marsupials. Still further, the "typical arrangement" of the intrinsic muscles into adductor, flexor, and abductor layers may in some respects be exceeded,[1] and the passage to the dorsum of the hand of the most dorsal part of the interossei may furnish an extensor layer. Such an arrangement is, according to Meckel,[2] met with in the hand of the Sloth (*Bradypus tridactylus*), and other mammifers.

Which of these conditions is to be regarded as typical may well be left an open question.

At the close of a recent paper[3] Dr Ruge expresses as his opinion, that to extend the division of these intrinsic muscles into three layers to all mammals is wrong, "especially as, according to Cunningham himself, 'fusion' of the dorsal and intermediate layers is extremely common."

It is difficult to understand why the "fusion" of two previously existing layers, however common, should in any way militate against the view that the separate condition was more typical than the coalesced; conversely, indeed, if the fact of their fusion in all cases be established, it certainly seems to favour Dr Cunningham's views of the "type" arrangement. Ruge prefers, he goes on to say, to regard the threefold separation of the muscles as secondarily derived from two original layers—interossei and contrahentes. The contrahentes he defines as including all those muscles which lie superficial to the deep branch of the external plantar nerve and its branches, and the interossei as those over which the deep branch runs. The interossei, however, themselves consist of two layers, even in the early embryo. So that, here again we have really to do not with a bi-laminar but with a tri-laminar arrangement, though

[1] Since writing the above, Dr Cunningham has kindly shown me his dissections of the intrinsic muscles in the foot of the Cuscus (*Phalangista maculata*). In this animal the differentiation of an additional or *fourth* series of muscles constitutes an "approximator" group.

[2] *Loc. cit.* vol. vi. p. 351. See also Macalister "On the Anatomy of *Chlamydophorus truncatus*, with Notes on the Structure of other species of Edentata." *Trans. Roy. Irish Acad.* 1875. (Science) p. 219.

[3] "Zur vergleichenden Anatomie der tiefen Muskeln in der Fusssohle," *Morph. Jahr.*, vol. iv. p. 644.

not that of Cunningham. Ruge further points out that in some groups, as in the Carnivora, the interossei form but one division, a coalescence having taken place. This of course is essentially different to the fusion of the dorsal and intermediate layers of Cunningham.

The actual condition of a single dorsal layer of interossei, under any circumstances, is intelligible enough, but whether in different cases it is to be regarded as resulting from the fusion of previously existing separate elements, or rather as indicatory of commencing differentiation is doubtful. The constant changes which evolution predicates and necessitates render it probable that both conditions may be found.

Explanation of Plate VII.

Fig. 1. Left hand of the Opossum (*Didelphys V.*), natural size, showing the palmar layer of muscles—*ad. p.*, adductor pollicis; *ad. i.*, adductor indicis; *ad. a.*, adductor annularis; *ad. m.*, adductor minimi digiti. Other structures which do not belong to this group are lettered as follows:—*ab. p.*, abductor pollicis; *ab. m.*, abductor minimi digiti; *o. m.*, opponens minimi digiti; $f.^1$, $f.^2$, $f.^4$, $f.^5$, as in fig. 2; *f. c. u.*, tendon of flex. carpi ulnaris; *f. c. r.*, tendon of flex. carpi radialis; *e. o. m.*, tendon of ext. ossis metacarpi pollicis.

Fig. 2. Same hand, showing the intermediate layer of muscles. The adductors as well as the abductors of the first and fifth digits have been removed—$f.^1$, flexor brevis pollicis; $f.^2$, flexor brevis indicis; $f.^3$, flexor brevis medii; $f.^4$, flexor brevis annularis; $f.^5$, flexor brevis minimi digiti; other letters as in fig. 1.

Fig. 3. Same hand showing the dorsal layer of muscles (dorsal aspect)—$d.^1$, $d.^2$, $d.^3$, $d.^4$, indicate the respective dorsal interossei; the remaining muscles of this layer, viz.—the abductor pollicis and the abductor minimi digiti, are shown in fig. 1.

Fig. 4. Left hand of the Wallaby (*Halmaturus ualabatus*), natural size, showing the palmar layer of muscles. Remarks and letters in fig. 1 apply equally to this figure; the sketch shows also the slender accessory slips to the adductors of the first and fifth digits, which are described in the text.

Fig. 5. Same hand as in fig. 4, showing the dorsal interossei (dorsal aspect). These are lettered $d.^1$, $d.^2$, $d.^3$, $d.^4$ respectively. On comparison with fig. 3 the difference of the planes of insertion will be evident.

Fig. 6. Shows the same muscles as fig. 5 (palmar aspect). The lettering corresponds to that of fig. 5.

MYOLOGY OF VIVERRA CIVETTA. By ALFRED H. YOUNG, M.B., &c., *late Assistant Lecturer on Anatomy, The Owens College, Manchester.*

THE muscular anatomy of the Civet (*Viverra civetta*) has already been described, more or less completely, by Meckel,[1] Devis,[2] and Macalister.[3] The following notes are simply intended to supplement these descriptions, and to supply such omissions as have been found to exist. It is hoped that the myology of the Civet will thus be made available for comparative purposes.

MUSCLES OF THE HEAD AND NECK.

The facial muscles are well developed; they include an *orbicularis palpebrarum* encircling the orbit, and an *orbicularis oris* which surrounds the mouth; the latter, in addition to a posterior bony attachment, has also an anterior one to the maxillary alveolar border just above the incisor teeth, whilst a few of its external fibres pass to the lateral nasal cartilages. There is a strong *levator labii superioris et alæ nasi* and a rudimentary *levator auguli oris.* The *buccinator* is well marked.

The frontal moiety of the *occipito-frontalis* is prolonged as a thin superficial muscular sheet which blends with the orbicular muscles, both in the orbital and buccal regions.

The muscles of mastication are arranged in the manner usually found amongst carnivores.

The *temporal* is very strong, and, as in Hyænidæ, not easily separable from the *masseter.* This latter muscle, which has its usual attachments, is only divisible to a slight extent, and that posteriorly, into two strata.

Of the two *pterygoid* muscles the external is very small, and, as in carnivores generally, is apparently antagonistic to the

[1] *Anatomie Comparée.*

[2] "Notes on the Myology of Viverra Civetta," *Journ. of Anat. and Phys.* vol. ii. p. 205.

[3] "The Muscular Anatomy of the Civet and Tayra," *Proc. Roy. Irish Acad.* vol. i. ser. 2, p. 506.

much more powerful internal pterygoid. Neither of these muscles present anything remarkable in their attachments.

The auricle is furnished with superficial and deep *cervico-auriculares* from the ligamentum nuchæ and external occipital protuberance respectively, to the dorsum of the conchal cartilage. A thin sheet of fleshy fibres arises from the temporal fascia immediately above the zygoma, passes to the ear, and divides into two slips, one of which is attached to the anterior margin, and the other (deeper) to the dorsum, of the concha; this muscle apparently represents the *temporo-auricularis externus et internus.* The *zygomatico-auricularis* from the back of the zygoma runs to the base of the concha superiorly.

Sterno-mastoid is quite distinct from the *cleido-mastoid*, and considerably exceeds it in size. The *digastric* is thick, and is inserted into the middle third of the lower border of the mandible; it is not marked by any indication of a median tendon.

The *sterno-hyoid* and *sterno-thyroid* arise in common, but soon separate and have their usual insertions. The *thyro-hyoid* is normal in origin and insertion, so also a well-marked *crico-thyroid.* The *omo-hyoid* is absent. The *mylo-hyoid, genio-hyoid*, and *genio-hyo-glossus*, present no deviations from their normal arrangements and connections.

The *hyo-glossus* is comparably feeble. Devis[1] describes it rightly as turning forward and playing over the arch of the hyoid cornu, as over a pulley.

The *stylo-glossus* is strong and wide. Its origin is from the middle of the stylo-hyal bone. I was not able to distinguish the thin flattish stylo-hyoid noted by Macalister; but there is a masto-hyal running from the para-mastoid process to the stylo-hyal bone, such as Macalister describes in the Tayra.[2]

Scaleni.—Three in number, are as described by Macalister. A well-marked *longus colli* is arranged as in *Hyæna crocuta*[3] and most carnivores. The *rectus capitis anticus major*, from the second to the seventh cervical transverse processes, and the *rectus minor* from the transverse process of the atlas, are inserted together into the basi-occiput.

Splenius arises from posterior two-thirds of the ligamentum

[1] *Loc. cit.* p. 209. [2] *Loc. cit.* p. 507.
[3] *Proc. Zool. Soc.* Jan. 1879, p. 93.

nuchæ, and from the anterior four dorsal spines; the greater part of the resulting muscle passes to the transverse ridge of the occiput and forms a *splenius capitis;* the remaining part of the muscle, corresponding to that portion arising from the last two dorsal spines, is joined by deeper fibres from the fourth and fifth dorsal transverse processes, and is inserted into the transverse processes of the last five cervical and the first dorsal vertebræ. This cervical attachment, constituting a *splenius colli,* is not usually found in carnivores, and does not appear to have existed in Macalister's specimen. Douglas[1] notes a cervical insertion of the splenius in the dog.

Complexus.—This muscle arises from the two posterior cervical articular processes, the three anterior dorsal transverse processes, and also from the middle line, reaching from the centre of the ligamentum nuchæ as far back as the fourth dorsal spine. Its insertion is into the occiput as usual; the muscle is marked by a tendinous intersection.

Complexus tertius.—Under cover of the complexus, a series of muscular slips, lying external to the spinalis colli, spring from the transverse processes of the anterior three dorsal vertebræ, and also from the articular processes of the posterior four cervical; the fibres, which pass over two or three vertebræ, are inserted into the laminæ of those in front as far forwards as the atlas. A similar muscle has been described in *Hyæna brunnea,*[2] *Hyæna crocuta,*[3] and *Hyrax capensis.*[4]

Of the sub-occipital group of muscles the *inferior oblique* is by far the largest; the *superior oblique* is inseparable from the outer margin of the complexus. The *rectus cap. post. major* is strong and bilaminar. *Rectus cap. post. minor* has its usual position and attachments.

The *spinalis colli* extends from the sides of the anterior three or four dorsal spines to the spines of the cervical vertebræ as far forwards as the axis. Devis notes that a slip from the longus colli is given to this muscle opposite each vertebra; this certainly is not the case in my specimen.

[1] Douglas, *Myographiæ Comparatæ*—specimen (1707), p. 78.
[2] Murie, *Trans. Zool. Soc. Lond.* vol. vii. p. 511.
[3] *Proc. Zool. Soc.* Jan. 1879, p. 94.
[4] Mivart and Murie, *Proc. Zool. Soc.* 1865, p. 333.

MUSCLES OF THE BACK, THORAX, AND ABDOMEN.

The *trapezius* is very extensive; it arises, broad and fascial, from the occipital crest, and reaches as far back as the tenth dorsal spine. The anterior or clavicular part of the muscle is joined on its deeper aspect by an accessory band which springs from the paramastoid. The fibres are prolonged, to be inserted low down on the anterior surface of the humeral shaft, on a line with the delto-pectoral ridge. There is a clavicular tendinous intersection.[1] The remaining or scapular portion of the trapezius is inserted into the spine of the scapula.

A *trachelo-acromial* is described by Devis[2] as "blending imperfectly with the rhomboideus." Macalister,[3] on the other hand, states that "it is inserted remote from the rhomboid, at least 2·1 inches from it;" Meckel[4] also notes its presence in viverra. In my specimen the trachelo-acromial does not exist as a separate muscle.

Rhomboideus has no occipital attachment, its origin is from the middle line reaching from the spine of the axis to the fourth dorsal spine. The *latissimus dorsi* is small, and arises from the posterior nine dorsal spines and lumbar aponeurosis. As in Hyæna there is no costal attachment. Its insertion is intimately united with that of the *teres major*, and with the humeral attachment of the *panniculus*. It sends off a well-marked *dorso-epitrochlearis* to the ulnar side of the olecranon.

Serratus magnus springs from the last six cervical, and the first dorsal transverse processes; its costal slips come from the anterior eight ribs, excluding the first. Its insertion is into the ventral aspect of the spinal border of the scapula.

Superior and inferior *serrati postici* are distinguishable only by the different direction of their fibres.

The subdivisions of the *erector spinæ* are much as in *Hyæna brunnea*, or *H. crocuta;* the peculiar relationship as regards their size in these animals[5] is perhaps not quite so marked here.

Sacro lumbalis is very small, and only reaches to the last rib;

[1] The part of the muscle just described corresponds to the *levator humeri proprius* in *Hyæna crocuta*.—*Proc. Zool. Soc.* 1879, p. 97.

[2] *Loc. cit.* p. 208.

[3] *Loc. cit.* p. 507.

[4] *Anatomie Comparée*, vol. vi. p. 237.

[5] *Proc. Zool. Soc.* 1879, p. 95.

a fairly developed *musculus accessorius* is prolonged to the first rib, whilst a few muscular fibres, continued to the transverse processes of the posterior two cervical vertebræ, form the only representative of a *cervicalis ascendens.*

The *longissimus dorsi* is separated from the sacro lumbalis by the elevator caudæ; a *transversalis cervicis* reaches up to the last three cervical transverse processes. This latter muscle is much weaker in the Civet than in Hyæna. In the former, however, there is a *trachelo-mastoid,* which is absent in the latter; this muscle is somewhat peculiar, inasmuch as at its origin it is separated from the transversalis cervicis by the cervical insertion of the splenius.

Spinalis dorsi is very strong; it extends to the fifth cervical spine.

The *Intercostales* are arranged as usual, so also the *levatores costarum.*

There is a single *supracostalis* from the middle third of the sternum to the first rib.

The *rectus abdominis,* as usual in carnivores, is prolonged to the first rib.

The abdominal muscles are arranged in the usual manner.

A *Quadratus lumborum* from the ilium posteriorly reaches as far as the first lumbar transverse process. It is very feeble; no fibres pass to the last rib.

There is a *psoas parvus,* which is largely fascial, and a well-marked *psoas magnus;* this latter is joined by a small *iliacus;* the two muscles take their usual insertion.

The *coccygeus* is well developed. The muscles of the tail agree closely with those of the Hyæna.[1] They are, however, comparatively larger, and take more extensive origins.

Muscles of the Fore Limbs.

Pectoralis major.—This muscle consists of three strata; one superficial, arises from the presternum, and also the mesosternum as far back as the junction of the fifth costal cartilage, it passes to the lowest part of the delto-pectoral ridge. The deepest stratum has more extensive attachments. It arises from the whole

[1] *Proc. Zool. Soc.* 1879, p. 26.

length of the sternum, except the presternum, and is inserted beneath the superficial part, reaching up as far as the head of the humerus; the lowest fibres pass to the fascia over the biceps, and appear to correspond to the xiphi-sterno-humeral of Macalister.[1] Between the superficial and deep strata an intermediate set of fibres runs to the pectoral crest immediately above the insertion of the superficial.

Macalister describes accurately a fourth pectoral, "or the brachio-lateral part of the panniculus."

The *pectoralis minor*, as usual in carnivores,[2] is wanting.

The *deltoid* consists of acromial and scapular portions, which are inserted together on the delto-pectoral ridge. The clavicular portion described by Macalister as passing down to a radial insertion, corresponds to those fibres of the trapezius previously described, which are below the clavicular intersection. In my specimen they did not reach to the radius.

The scapular muscles are all arranged in the usual manner. The *teres minor* is distinct. The remaining muscles of the upper arm include a short *coraco-brachialis*, a *biceps*, coracoid in origin and entirely radial in insertion; a strong *brachialis anticus*, ulnar in insertion, and a powerful *triceps*. There is also a well-marked *anconeus externus*.

In the fore arm a strong *pronator radii teres* has an extensive insertion into the lower half of the external border of the radius; the *pronator quadratus* occupies the lower third of the radius and ulna.

The flexor group comprises a *F. carpi radialis*—to the second metacarpal—and a separate *F. carpi ulnaris* (the condyloid and olecranal heads of which soon unite), inserted into the pisiform and fourth metacarpal bones. The *palmaris longus* is double, and forms two slender muscles, the tendons of which pass separately into the palm.

Flexor profundus is as described in detail in Hyæna.[3] It consists of a large muscular mass, ending inferiorly in a broad tendon, from which slips are given off to the five digits.

The superficial fibres of this mass constitute a *flexor sublimis*, they end on three delicate tendons, which pass to the three

[1] *Loc. cit.* p. 508.

[2] Cuvier, *Leçons d'Anat. Comp.* vol. i. p. 256.

[3] *Proc. Zool. Soc.*, Jan. 1879, p. 99.

middle digits, and are disposed in the usual manner. The outermost digit, however, is not devoid of a superficial flexor, but is furnished with a special palmar muscle, which takes origin from the annular ligament, the pisiform bone, and from the ulnar tendon of the palmaris longus; its tendon passes to the fifth digit, and, after being pierced by the corresponding deep tendon, is inserted into the second phalanx.

Devis [1] refers to this muscle, and calls it an "accessorius." It appears to correspond to what Murie and Mivart [2] term the "flexor brevis manus" in the *Hyrax capensis.*

A small but similar slip runs in the Civet to the fourth digit. It joins the proper flexor perforatus tendon.

The *supinator longus* is distinct and normal; there is also a strong *supinator brevis*, with the usual connections.

The extensor group includes—*Extensores carpi rad. longiur et brevior* more or less inseparable, a strong *ext. carp. ulnaris*, and a well-defined *ext. communis digitorum.*

The *ext. minimi digiti* terminates in three tendons, which are distributed to the three outer toes. They join the tendons of the common extensor. A conjoined *ext. secundi et indicis* springs from the posterior border of the ulna, and is distributed to the pollex and index.

The *ext. ossis. met. pollicis* is very large; it arises from both radius and ulna, and is inserted solely into the metacarpal of the thumb. There is no separate ext. primi internodii.

Lumbricales are four in number. They pass to the four outer digits, and are arranged in the usual manner, thus differing from Hyæna.[3]

The intrinsic muscles of the hand consist of an *adductor pollicis, adductor minimi digiti*, and a small *adductor indicis.* There are also distinct abductors and flexors of the great and little toes respectively. Neither is furnished with an opponens. The remaining digits have associated with them flexores breves, arranged in pairs in relation to each metacarpal shaft. It is interesting to note that the radial belly of the flexor brevis of the index digit is joined by a strong slip from the metacarpal of the pollex, which forms an abductor.

[1] *Loc. cit.* p. 213.

[2] *Proc. Zool. Soc.* 1865, p. 341.

[3] *Loc. cit.* Jan. 1879, p. 100

Muscles of the Hind Limbs.

Gluteus maximus (*externus*) arises from the fascia covering the gluteus medius and muscles of the back, as well as from the three anterior caudal vertebræ. The anterior fibres, which are with difficulty separable from the tensor fascia femoris, are inserted into the fascia lata.

The arrangement of the posterior fibres is remarkable. They form small but distinct muscular bundles disposed in two strata. The superficial stratum comprises four such bundles, and the deep, three. All the superficial bundles, with the mesially placed of the deeper three, are inserted into the shaft of the femur, and reach down to its lower third. The anterior of the deep bundles passes under cover of the biceps to end below it in the fascia on the outer side of leg; whilst the posterior bundle joins the semi-tendinosus half-way down the thigh, and constitutes its caudal origin.

Gluteus medius and *gluteus minimus* are normal and separate; there is also a *gluteus quartus*, from the acetabular border of the ilium to an insertion with the minimus into the great trochanter, and a *gluteus quintus* from the anterior border of the acetabulum, over the rectus tendon, to the anterior intertrochanteric line. This corresponds to the gluteus quartus of the Spotted Hyæna.[1]

The *pyriformis* is quite distinct from the gluteus medius, and is inserted with it. The great sciatic nerve passes below this muscle.

The *gemelli* are united beneath the tendon of the *obturator internus* with which they are inserted. The *obturator externus* and *quadratus femoris* have their usual attachments.

Biceps with a narrow origin from the tuber ischii, has a wide insertion into the upper half of the fascia on the outer side of the leg; a *bicipiti accessorius* corresponds to the muscular slip described in connection with the gluteus maximus, as being inserted below the biceps; it does not receive any slip from the semi-tendinosus.

Semi-membranosus is quite distinct from the adductor mass; its insertion is into the internal tibial tuberosity. Meckel[2]

[1] *Loc. cit.* 101. [2] *Loc. cit.* vol. vi. p. 386.

describes the union of the semi-membranosus with the adductor to be usual in carnivores—but notes its existence as a separate muscle in Hyæna, Bear, Racoon, and Coati. Macalister[1] also found it "quite separate from the adductor primus in *Galera*, not so in *Viverra*."

The *semi-tendinosus*, has an ischiatic origin in common with the biceps. It also receives a caudal slip. The two heads unite about half-way down the thigh, the union being marked by a tendinous intersection. Insertion is into the tibia beneath the gracilis.

The *sartorius* is single, with a broad insertion into the patella as well as into the tibia. In Hyæna crocuta[2] this muscle is double; so Macalister found it in the Civet, whilst he notes its undivided character in the Tayra.

The *gracilis* presents the ordinary relations.

Pectineus, which both Devis and Macalister describe as small, I find very large, and possessing an extensive insertion, which reaches half-way down the femoral shaft. The muscle is double at its insertion, and its superficial fibres may represent an adductor longus, such as Macalister[2] notes in Galera. The distinction between the vastus internus and crureus, is somewhat more strongly defined than usual, otherwise the *quadriceps extensor* presents no deviation from the regular arrangement. Its components present the ordinary relations and attachments.

The *adductor* muscles are as described by Macalister,[3] except that the adductor primus is quite distinct from the semi-membranosus. In this respect *Viverra* also differs from *Hyæna crocuta*,[4] otherwise with the exception that in the Civet the adductor secundus (A. brevis in Hyæna) is easily separable into two planes, the muscles are identical in the two animals.

The *gastrocnemius* arises by two heads, of which the external is the larger;—a fabella exists in the outer head only—Its insertion below is into the os calcis; a separate *soleus* arises from the head of fibula, and from the fascia attached to the external border of the tibia; its tendon, separated from that of the gastrocnemius by a bursa, is inserted along with the latter into the os calcis. The *plantaris* tendon passes the tuberosity of the os calcis, and,

[1] *Loc. cit.* p. 511.
[2] *Loc. cit.* p. 511.
[2] *Loc. cit.* p. 103.
[4] *Loc. cit.* p. 102.

expanding on the sole, forms the origin of the flexor brevis digitorum.

The *popliteus*, comparatively large, has the usual attachments; it reaches down nearly to the middle of the tibia. *Tibialis posticus* arises from the posterior surfaces of both tibia and fibula and passes to the scaphoid.

The *flexor longus digitorum* is tibial in origin; its tendon runs into the sole, and is there joined by that of the *flexor longus hallucis;* the resulting broad and flattened tendon divides into five, which are distributed to the respective toes in the usual manner.

A *flexor accessorius*, from the external surface of the os calcis, joins the common tendon superficially; its fibres seem, however, to be more particularly prolonged towards the tendinous slip distributed to the great toe.

The *flexor longus hallucis*, fibular in origin, is quite separate from the flexor longus digitorum in the leg.

Flexor brevis digitorum (perforatus), as previously stated, springs mainly from the tendon of the plantaris, as in Hyæna striata, and Cat;[1] additional fibres, however, come from the os calcis. It terminates in four tendons, for the outer toes, each of which receives a small muscular slip from the common deep flexor tendon. These little slips, which are given off just before the division of the deep tendon, seem to correspond to the so-called lumbricales in *Hyæna striata*[2] and *Hyæna crocuta.*[3]

In the Civet there are also four *lumbricales*, which are arranged in the usual manner.

Peroneus longus, with a fibular origin, is inserted into the fifth and first metatarsals. *Peroneus brevis*, from the upper two-thirds of the fibula, goes to the fifth metatarsal. There is also a third peroneus ("peroneus quinti," Macalister), which arises behind the peroneus brevis; its tendon joins that of the extensor of the fifth toe. Devis[4] describes this muscle under the name of the "*Extensor proprius quinti digiti.*"

Tibialis anticus is large. It possesses both tibial and fibular origins, and is inserted into the metatarsal of the hallux.

[1] Meckel, vol. vi. p. 451.
[2] Cuvier and Laurillard, "*Recueil de Planches de Myologie*," Pl. 141, fig. 3.
[3] *Proc. Zool. Soc.* 1879, p. 104. [4] *Loc. cit.* p. 217.

The *extensor hallucis* is quite separate but small, its origin, from the fibula below that of the tibialis anticus, measures only about half an inch; it is inserted solely into the phalanges of the great toe.

The *extensor longus digitorum* is, as usual in carnivores, femoral in origin. Its tendons are distributed to the four outer toes; an *extensor brevis digitorum* springs from the os calcis, and gives tendons to the four inner toes.

The intrinsic muscles of the pes are arranged very much like those of the manus. The adductor group consists of three muscular slips, all situated in the same plane, which spring from the ligamentous structures beneath the distal tarsal bones, and are distributed so as to constitute adductores minimi digiti, hallucis, and indicis, respectively. Another set of fibres, very slender but distinct, arising with the adductors and occupying the same plane, is inserted just below the middle of the fifth metatarsal shaft, and forms a rudimentary opponens minimi digiti.

The great and little toes are each provided with well-defined and separate abductors and double bellied flexores breves. A small muscle from the ento cuneiform and scaphoid bones to the proximal end of the metatarsal of hallux is the only representative of an opponens hallucis.

The remaining toes possess each a pair of small muscles, corresponding in position and arrangement to the flexores breves of the first and fifth toes. The insertion of these muscles is partly into the proximal phalanges, and partly into the extensor tendons of the respective toes. Their function is principally that of flexors of the first phalanges, but acting separately they may abduct or adduct the toes, whilst, by virtue of their insertion into the extensor tendon, they assist in extending the distal phalanges.

The Civet, therefore, so far as regards the intrinsic muscles of the manus and pes, does not seem to exhibit so complete a differentiation into distinct adductor, flexor, and abductor layers, as Dr Cunningham[1] describes in other pentadactylous carnivores, but agrees rather with the tetradactylous species, in the posses-

[1] "On the Intrinsic Muscles of the Mammalian Foot," *Journ. of Anat. and Phys.* vol. xiii. p, 9.

sion of a distinct plantar layer of adductors, whilst the flexores breves and dorsal interossei are not distinguishable throughout as separate layers.

Concluding Remarks.

A comparison of the muscular system of the Civet with that of the Hyæna is, in view of the close affinities which exist between the Viverridæ and Hyænidæ, of considerable interest. Such differences as may be distinguished by comparing the muscles of *Viverra civetta* with those of *Hyæna crocuta* may be briefly summarised as follows:—

In the Civet the cleido-mastoid is distinct from the sterno-mastoid; there is also a well-marked splenius colli, and a separate trachelo-mastoid. Three scalene muscles are distinguishable, but in this respect, one species of Hyæna[1] (*Hyæna brunnea*) agrees with the Civet. In the fore limb of Viverra the presence of a long supinator and a flexor brevis manus, together with the double nature of the palmaris longus, the absence of an ulnar insertion of the biceps, and the more marked development and differentiation of the hand muscles, is in striking contrast with what obtains in Hyæna.

The hind limb of the Civet possesses an additional gluteus (quartus), and a semi-membranosus, which is not attached to the adductor. There are also a well-developed soleus, and three separate peroneal muscles. Other points worthy of note are to be observed in the undivided condition of the sartorius, the double insertion of the pectineus, the caudal origin of the semi-tendinosus, and the prolongation of the plantaris tendon to form an origin for the flexor brevis digitorum, whilst in the foot, as in the hand, the intrinsic muscles are well-developed and differentiated.

In all these respects the Civet differs from the Hyæna; the enormous development of the muscles of the neck and fore-quarters in the latter animal, which is so characteristic of its genus, has no counterpart in the Civet.

[1] Murie, *Trans. Zool. Soc.* Lond. vol. vii.

NOTE ON THE ANATOMY OF THE KNEE JOINT.

By W. Roger Williams, M.R.C.S. L.R.C.P. Lond., *Assistant Demonstrator of Anatomy at University College, London.*

In reflecting the skin from the front of the knee joint we find it adheres firmly to the subcutaneous fascia over the patella and the tibial tubercle, so that if we wish to effect the separation we must proceed carefully; with this precaution we shall nearly always find a bursa, about the size of a shilling, between these structures, over the lower part of the patella.

This is the only pre-patellar bursa that is, strictly speaking, *subcutaneous.*

The skin is much thicker over the patella, ligamentum patellæ, and tibial tubercle, than at the sides, where it is but loosely connected with the subcutaneous fatty tissue.

We cannot fail to notice, when reflecting the subcutaneous layer, that it is thick and abounding in fat on each side of the joint, whilst in front, over the patella, ligamentum patellæ, and tibial tubercle, it is thin and membranous; so that on holding it up to the light when detached, a correct impression of these parts becomes visible by their translucency. This subcutaneous layer is but loosely adherent to the underlying fascia lata, over which, with the skin, it is freely movable. Between these structures, along the front of the joint, I have frequently found a remarkable *series of bursæ,* sometimes intercommunicating, sometimes quite separate; the highest, situated over the lower part of the patella, often encroaching slightly on the ligamentum patellæ, a middle one placed over this ligament, and the lowest over the anterior tibial tubercle (superficial pretibial bursa). One or more of these bursæ is almost always present.

Having completely removed this subcutaneous tissue, we are in a position to examine the fascia latal investment. It completely covers the front of the joint, passing from the inner side, where it is blended with the sartorius and the quadricipital expansion, over the patella, &c., to the outer side, there to be fixed to the ilio-tibial band.

By reason of these connections the sheath which it forms

round the joint is divided into an anterior and posterior compartment.

This investment is movable over the patella, and most of the front and outer part of the joint, being continuous above with the fascia lata of the thigh.

The fibres have a transverse arrangement over the front of the joint: it is a band of these fibres, passing over the quadricipital tendon just above the patella, that binds this tendon down and so causes the slight concavity normally existing there, but which is lost as soon as this fascia is cut. On the inner side of the joint its fibres pass nearly vertically downwards, over those of the aponeurosis of insertion of the sartorius, the two sets of fibres crossing at right angles and becoming intimately blended.

The slight concavity of the ligamentum patellæ is due to a similar band passing in front of it, from the sartorius and fascia lata internally to the ilio-tibial band externally. The effect of cutting these fibres is very marked.

It is a common error to mistake the transverse fibres now visible for the lateral ligaments of the patella; but a little care will show that the fascia simply passes over the knee-cap without having any attachment to it.

To display the patellar ligaments, which I am surprised to find altogether ignored by the latest writer on arthrology, we must make a vertical incision from the middle of the thigh over the front of the patella, &c., and turn the resulting fascial flaps inwards and outwards. It will be found that the outer flap separates readily; the inner one, consisting of the insertion of the sartorius blended with the fascia lata, rather less so, because at its lower part it is connected with the expansion of the quadriceps.

In effecting this separation we open a large bursa over the front of the patella, usually about the size of half-a-crown—it is *the patellar bursa* par excellence; situate beneath the fascia lata, between it and a band of oblique fibres which pass from without inwards across the front of the patella, generally spoken of as the quadricipital expansion, but about which I imagine very clear ideas do not prevail; this bursa is generally single, but not unfrequently multilocular. Such a condition may arise either from the quadricipital expansion being incomplete or

cribriform, in which case the bursa communicates with a still deeper one situated beneath this expansion; or it may result from a perforation of the fascia lata by which the bursa opens into the one superficial to it. I have often seen cases in which these three bursæ formed one large multilocular sac, the remnants of the original septa in the form of irregular bands running across the bursal cavity; and I think it nearly certain that these bands are not unfrequently the real starting-point of the melon-seed bodies often found in the bursa when inflamed.

Having turned back the fascia lata from the outer side of the joint we can see the external lateral ligament of the patella.

This is really an offset from the ilio-tibial band, which is fixed to the lower half of the outer border of the patella. It is connected above with the insertion of the vastus externus, which, as will be remembered, is attached to the upper half of this border; and it is fortunately very thick, forming, as it does almost the only covering for this part of the joint, its deep surface being in contact with the synovial capsule.

The great strength of this ligament no doubt adds to the stability of the patella; but it seems to me that M. Tillaux, the latest French writer on surgical anatomy, has rather over-stepped the mark in ascribing to it an important influence in fracture of the patella. According to this author[1] the gravity of such a case will depend on the state of this ligament; if it remain entire, it will hold the fragments together, but in the event of its being torn they will be widely separated. This explanation, however, scarcely accords with the anatomical facts, for the ligament, being fixed only to the lower half of the patella, can have no influence in maintaining the fragments in apposition.

On turning back the inner flap we raise with it some fibres of the insertion of the sartorius, which unite with and strengthen the fascia latal envelope at this part; but further separation is prevented by the blending of the fascia lata with the subjacent quadricipital expansion. However, with a little aid from the scalpel, there is no difficulty in completely isolating this expansion. It is of a triangular shape, springing by its base from the tendons of the vastus externus, rectus, and vastus internus, at

[1] *Anatomie Topographique avec applications à la chirurgie*, p. 965, deuxième édition.

about an inch above the patella, by far the largest number of fibres being derived from the vastus externus. The band thus formed, narrowing as it descends, passes obliquely from without inwards across the front of the patella—over which it slides readily—to the inner side of the tibia, where it is fixed by its apex just below the inner tuberosity; here it blends with internal lateral ligament of the knee joint, whence Cruveilheir spoke of it as forming an accessory internal lateral ligament. Its tibial attachment is overlaid by the tendinous laminæ of the sartorius, gracilis, and semitendinosus. I am greatly indebted to Professor Turner for calling my attention to an article by John Goodsir on the anatomy of the knee joint,[1] in which this distinguished anatomist has described with great perspicuity the physiological import of many structural details in connection with this joint. I was thus led to consider the use of the quadricipital expansion, which I have shown is made up chiefly of fibres from the vastus externus. The considerable strength of the band seems to indicate important function. The whole expansion would be tightened by contraction of the quadriceps, *i.e.*, during extension, and the obvious effect of this would be to cause an outward rotation of the leg. In short, I conclude that the outward rotation of complete extension is chiefly effected through this expansion.

In order to expose the internal lateral patellar ligament it is necessary to remove this expansion, which is best done by detaching its apex and turning it upwards. If the band is complete we usually find a bursa underneath, between it and the vertical fibres of the great extensor tendon, which are fused to the front of the patella. From the insertion of the vastus internus into the upper part of the inner border of the patella, a thin layer of fibres passes downwards beneath the quadricipital expansion, and in front of the inner part of the intercondyloid notch, internal to the ligamentum patellæ, to be attached to the edge of the inner tuberosity of the tibia anteriorly: this may be called the proper expansion of the vastus internus to distinguish it from the quadricipital expansion. Of this Goodsir says, "it assists directly in the outward rotation;" and though this may be admitted, I should not imagine, on account of its tenuity, that it

[1] *Goodsir's Anatomical Memoirs*, vol. ii. p. 228.

functions very actively. The internal lateral ligament of the patella which is now visible is fixed to the lower part of the inner border of this bone, being blended with the insertion of the vastus internus and with the upper part of its proper expansion. The ligament consists of a slight band of nearly transverse fibres, which pass from the inner condyle of the femur immediately below the tubercle for the adductor magnus tendon to the point just mentioned. It will be gathered from this description that the patella is covered in front by four distinct layers, not including the fibres of the quadriceps tendon fused to its front, viz., skin, superficial fascia, fascia lata, and quadricipital expansion, beneath each of which a separate bursa may be found. Since writing this description entirely from my own observations, Mr R. W. Lyell has called my attention to an article by Professor Volkmann in the *Handbuch der Chirurgie* of Pitha and Billroth, in which this eminent surgeon, following the monographs of several authors, has described and figured a somewhat similar condition.

From these considerations the following are a few of the most obvious deductions. Should the subcutaneous bursa suppurate, the resulting abscess will probably be circumscribed, owing to the intimate adhesion between the skin and the subcutaneous fascia, and it will most likely open in front. In the event of the bursa beneath the superficial fascia being similarly affected, there will be great danger of the pus diffusing itself over the front of the joint, and even of its passing behind to the popliteal space, on account of the slight connection between the superficial and deep fascia. The abscess will certainly be extensive if the bursa over the patella communicates with those over the ligamentum patellæ and the tibial tubercle, as is not unfrequently the case; and a further complication will arise should this bursa communicate with the one beneath the fascia lata. Supposing the latter bursa to suppurate without any such communication taking place, pus may still spread over the front of the joint; but it will not be likely to find its way round to the popliteal space because of the blending of the fascia lata with the iliotibial band on the one side, and with the expansions of the sartorius and the quadriceps on the other. A diffusion of pus at this level will appear more deeply seated than that

previously described, because of its being bound down by the strong fascia lata. Abscess seated beneath the quadricipital expansion, however, is the variety most likely to lead to serious mischief; for, being very closely confined, it would have a tendency to induce caries of the patella.

Many of the cases of so-called regeneration of the patellar bursa after its excision may be accounted for by one of the deeper bursæ becoming diseased, in consequence of the removal of its protecting pad.

In making the above dissection it will be noticed that the fatty cushion separating the ligamentum patellæ from the head of the tibia bulges in front on each side of the ligament. It has occurred to me that the thickening at this part of the joint in cases of chronic synovitis, which persists long after the fluid has been absorbed, causing great weakness, is due to the hypertrophic induration of this fatty mass.

Another little point to which I wish to call attention is, that a bursa, previously undescribed, almost invariably exists between the ilio-tibial band and the synovial doubling over the outer side of the external condyle of the femur.

The large bursa separating the quadricipital tendon from the front of the femur is often regarded as a synovial cul-de-sac; but I incline to the opinion of Cruveilhier and Tillaux that its origin is bursal and distinct from the synovial membrane. In about twenty-five cases I examined I found only two in which it was quite separate from the joint, and this nearly corresponds with Tillaux's figures. In not quite half the cases the remains of a septum were obvious—the central perforation varying in size from a threepenny piece to a florin.

In addition to this I have found three other small elongated bursæ grouped round the upper part of the patella:—

(1.) *Median*, situated in front of the subquadricipital bursa, intervening between the back of the extensor tendon and the sharp posterior edge of the patellar base.

(2.) *External*, where the vastus externus plays over the sharp outer edge of the intercondyloid notch, a small bursa intervenes between the tendon and the synovial reflection. It is generally separate.

(3.) *Internal*, interposed between the doubling of the synovial

pouch over the inner edge of the intercondyloid notch and the tendon of the vastus internus.

In one case I found the last mentioned bursa communicated by a small opening with the median one, which opened in its turn by a similar orifice into the front of the subquadricipital bursa. I think many of the tumours apparently not communicating with the joint, observed round the upper part of the patella, may be due to disease of these bursæ.

In conclusion, I would add a few words about a structure called by some writers the posterior internal lateral ligament of the knee joint. It is simply a band of fascia lata, situated nearly an inch behind the internal lateral ligament, which serves to bind down the tendinous laminæ of the gracilis and semitendinosus as these bend forward to their tibial insertion. Attached above to the inner condyle, just below the tubercle for the adductor magnus, it passes down as far as the upper border of the gracilis, where it splits into two layers, one of which descends over the tendon of the gracilis, between it and the sartorius, and blends with the fascia lata covering the gastrocnemius; the other passes over the semitendinosus, between it and the gracilis, blending below with the aponeurotic expansion of this muscle, the fascia lata, and the tibial periosteum.

ON THE DEVELOPMENT OF FIBROUS TISSUE FROM THE HEPATIC PARENCHYMA, IN CIRRHOSIS OF THE LIVER. By D. J. HAMILTON, M.B., *Demonstrator of Pathology, University of Edinburgh; Pathologist to the Edinburgh Royal Infirmary.* (Plate VIII.)

IN a paper by MM. Kiener and Kelsch (*Archives de Physiologie normale et Pathologique*, August 1879), I was gratified to find that they had described appearances in cirrhosis of the liver, relating to the origin of the fibrous tissue from liver cells, which have been familiar to me for some time past, and which I have had opportunity of verifying in several instances. In most particulars their description of these appearances is, according to my experience, correct; but there are some points unnoticed by them which seem to be of considerable importance in understanding what at first sight appears to be a very extraordinary feature in histogenesis. Their observations were in a manner anticipated by those of Dr J. Wickham Legg on the same subject, who, in 1872 (*St Bartholomew's Hospital Reports*), hinted at the probable origin of fibrous tissue in cirrhosis of the liver from the liver parenchyma. He did not very clearly illustrate how it is actually accomplished, but seemed undoubtedly to have met with appearances indicative of the transformation of the one into the other. Several authors had before this described what they considered to be the formation of fibrous tissue from liver cells, in experimental inquiries on acute hepatitis in animals; and although their observations were refuted by subsequent observers, such as Josef, there seems little doubt that what was described, for instance by Holm (*Wiener Sitzungsberichte*, 1867), was accurately stated and interpreted. The division, subdivision, and ultimate transformation of the liver cells into fibrous tissue, which he saw in the livers of certain animals, is strictly in keeping with what occurs in the human subject. Since these observations were made the subject fell into abeyance, until the paper above quoted, by MM. Kiener and Kelsch, has again brought it into notice.

It is usually supposed that the liver cells play a passive part in the cirrhotic disease; the individual lobules, or groups of lobules, being surrounded by fibrous tissue, are supposed merely to undergo atrophy from the pressure exerted upon them, but no higher power, such as that of constructing a new tissue, has generally been attributed to them. This is to be accounted for by the fact that in most cases the organ is in a quiescent state at the time of death, a state in which the previously formed cicatricial tissue is simply contracting on the liver lobules which it surrounds. In such a condition the liver cells exhibit no active changes, and are unsuited for the study of the manner in which the fibrous tissue is developed. There seems little doubt that in a cirrhosis of the liver, extending over a course of several years, exacerbations of a sub-acute nature occur every now and again, by which fresh cicatricial material is provided, while, in the intervals, the organ is in reality suffering from the mechanical effects of the contraction of this newly-formed tissue upon its secreting cells. The activity of the liver cells seems to vary according to the stimulation to which they are subjected by the presence of some irritant. It is, on this account, only occasionally that an opportunity is afforded of procuring an organ in which the acute proliferative changes are actually present at the time of death. In examining a series of cirrhotic livers one is, however, sometimes met with in which these acute or sub-acute changes are still in full activity, and in which the origin of the fibrous tissue found in the organ can be conveniently studied. It is from such that the following description is taken.

To the naked eye these organs present no distinctive feature. They have the usual small nodulated character, and are sometimes jaundiced, sometimes not. In each of the cases examined by me the atrophy of the organ was great, and in the furrows between the "hob-nail" projections on the surface, the capsule seemed to be much thickened and opaque.

A low-power view (50 diams.) is given of a section of one of these livers in fig. 1, running from the capsule inwards. Both layers of the capsule are present; the deep one (*b*) is immensely thickened, and sends processes inwards, which, after dividing and subdividing, surround and constrict portions of liver tissue. The superficial layer (*a*), however, which, in reality, is the re-

flected peritoneum, is not thickened, a condition which is constant in cirrhosis not occurring in a syphilitic subject, where a peri-hepatitis has usually been the commencement of the disease. Opposite each band of tissue running into the organ there is a depression of the capsule, corresponding to that seen by the naked eye between the "hob-nail" projections, while, on each side of this, the liver tissue is pushed forwards by the surrounding cicatrices. The cicatricial tissue is by no means deficient in blood-vessels; on the contrary, it can be seen that the branches of the hepatic artery (*e*) are more numerous than naturally. The young cicatricial elements could not organize were this not the case.

Special attention must be drawn to the numerous prominent nuclei seen throughout the section, both in the enclosed portions of liver tissue and in the cicatrices which surround them. The drawing is a representation of a preparation doubly stained in perosmic acid and picro-carmine. The manner in which the nuclei took on the carmine stain, after being mounted for a day or two, was most remarkable. It was so different from the faint tint which they ordinarily assume, that attention could not fail to be directed to it as something special. I have seen the same thing in certain other tissues, such as the epithelial cells in a scrotal cancer, and the nuclei of muscular fibres in acute myocarditis. In each of those cases the nuclei have been much enlarged, and have presented unequivocal evidence of multiplication by division. The whole of the carmine in the solution seemed to be precipitated on them, to the exclusion of the other tissues. What the change in the nucleus is which renders it so susceptible to colouring matters I do not know, but in every instance in which this facility has been observed a well-marked intra-nuclear protoplasmic plexus has been developed. It is probable that this renders the nucleus more susceptible to staining fluids.

These large nuclei, it will be seen (fig. 1), are present both in the liver lobules and in the cicatricial tissue, and there are situations (*h*) in which those of the one insensibly pass into those of the other. In the new-formed cicatricial tissue they either run in rows or are aggregated into rounded depots. The nuclei within the cicatricial tissue are as large as those in the liver cells, and, we shall see, are directly derived from them by a process of subdivision. Both possessed an equally great power of

staining with carmine. This was not observed in the blood leucocytes which lay beside them, so that a ready means of distinguishing the two was thus afforded, although independently of this their difference in size was sufficient for the purpose.

When examined with a higher magnifying power the cicatricial tissue was seen to be made up of the following constituents:— (*a*) white fibrous tissue; (*b*) spindle-shaped cells; and (*c*) rows of large and brightly stained nuclei (fig. 5, *a*, *b*, and *c*). An abundant plexus of capillary vessels ramified among it, and in their interior blood corpuscles of both kinds could be noticed. The leucocytes presented nothing unusual, and there was no evidence of their exuding in abnormally great numbers from the blood-vessels.

The large nuclei lying in the cicatricial tissue were seen to be round or oval in shape, and contained a nucleolus in their centre (fig. 5, *c*). They were from one and a half to four or five times as large as a leucocyte. There was a well-marked intra-nuclear plexus within each, such as that which has been described in various protoplasmic bodies by Flemming, Eberth, Heitzmann, Klein, and others. It is represented in the figure as a delicate network running through the nucleus, and giving it, when the fibres of the network are seen on optical section, a granular appearance. On altering the focus the true nature of this granularity could be discovered. The network appeared to be solid, and to consist of a substance denser than the surrounding parts of the nucleus. These nuclei were sometimes oval-shaped, and, when so, possessed a very delicate periplast, but the intra-nuclear network in no case ran into this.

The spindle-shaped cells (fig. 5, *b*, and 7) were more or less attenuated, according to their age. In the oldest, a delicate splitting of the periplast into fibrils could be observed, which ultimately developed into a bundle of white fibrous tissue, the nucleus remaining on one side as the nucleus of the bundle (fig. 5, *a*). These bundles of white fibrous tissue, when isolated, were seen to branch at their extremities, from the further splitting and separation of the fibrils. At the same time, as this process of fibrillation was going on, the fibrils were noticed to become more translucent, and to have lost the granular appearance which the periplast originally possessed. The free nuclei, those of

the spindle cells, and those of the fibrous bundles, all presented a similar intra-nuclear plexus.

The histogenetic relation of the three elements of the cicatricial tissue was evident on comparatively superficial observation. The free nuclei became oblong, and from their periphery a small quantity of a cement-like substance was secreted (fig. 5, *c*), which in course of time became drawn out into the tapering extremities of a spindle cell (fig. 5, *b*). The secretion from the periphery of the nucleus increased in quantity, and, as the part of it which was first secreted became pushed further outwards, it underwent the splitting into fibres previously described, these at the same time assuming the homogeneous aspect of white fibrous tissue (fig. 5, *a*). There is, therefore, a direct relationship between the three elements of the cicatrix, the youngest being the free nuclei, and the most completely developed the bundles of fibrous tissue. The fibres of the fibrous tissue I cannot look upon otherwise than as a secretion of the nucleus, and as corresponding to the periplast of a cell. We have thus traced the development of the fibrous cicatrix from the free nuclei described, but must go a step further back, in order to see from what these nuclei themselves arise.

On looking at the low-power drawing (fig. 1), it is evident that the liver-cell nuclei are not only more prominent objects than naturally, but also that their number is increased. In certain parts they are more abundant than in others, but throughout the whole preparation it is evident that great proliferation must have taken place. There is also, it will be observed, an entire absence of oil globules in the cells, which, if they had been present, would have shown with special distinctness on account of the preparation having been stained with perosmic acid. There is, further, no granularity or indistinctness of the liver cells, but, on the contrary, the outline of each cell can, even with this low magnifying power, be clearly differentiated. When examined with a higher lens, it was found that each liver cell contained either one or more nuclei, which were from three to five times larger than those of the normal cell, and were either placed centrically or excentrically in the cell body. They had the power of staining to the same inordinate extent with carmine as the large free nuclei previously referred to, as lying

in the cicatricial tissue. Each had a nucleolus and a well-marked intra-nuclear protoplasmic plexus (figs. 2, 3, and 4), which, however, did not seem to extend into, or communicate with, the cell periplast. Varying degrees of size and shape were noticed in these nuclei, corresponding to different stages in the process of proliferation.

The first thing to happen, when proliferation was about to take place, was the enlargement of the nucleus (fig. 2). This seemed to occur without any simultaneous growth of the periplast, and, at the same time, a nucleolus became distinctly visible in the centre, with a prominent intra-nuclear plexus around it.

Soon after this a depression was noticed at each side, so that the nucleus now came to have a dumb-bell shape (fig. 3), and as these deepened, a complete separation into two followed (fig. 4). As this division of the nucleus was proceeding, a transverse mark was seen running across the body of the cell opposite the point of separation of the two parts of the nucleus, which finally developed into a cleft, dividing the body of the cell into two (fig. 4). Two new cells were thus generated, and, when complete separation had occurred, it was found that the proportional size of the nucleus to the periplast was very much altered. For, while the nucleus continued to grow after division, and soon reached its original size, the periplast did not seem to keep pace with it.

The same process of division was repeated over and over again, so that, finally, a stage was arrived at in which the whole cell seemed to be made up of a much enlarged nucleus, with an almost imperceptible periplast, while ultimately the latter seemed to disappear entirely, a free nucleus being left.

Another manner of setting the nucleus free was noticed in some instances. After enlarging and dividing, it approached the border of the cell, and, forming a projection there, escaped from it and left a vacuole where it had existed. This, however, was not the commoner method, that formerly described being much more frequent.

The nuclei thus set free by either method accumulated in depots, or were arranged in lines (fig. 6), these sometimes being double, and, in this stage, they resembled and have frequently been described as bile-ducts. In several works on cirrhosis

of the liver, double rows of such nuclei, sometimes enclosing a space or apparent lumen, have been described by different observers. At first sight they certainly look like such; but, on a little careful attention being given to the point, the fact of their not being bile-ducts can easily be shown. As the division of liver-cells goes on, in the manner just described, adjacent rows of them come to lie closely together, and, being compressed by the surrounding cirrhotic fibrous tissue, they are forced into as small a space as possible (figs. 6 and 7). The periplasts in time disappear, and, as a result, the nuclei are left in a denuded state and arranged in rows. If two such rows, as commonly happens, lie closely together, they look very like the epithelium lining a tube of some kind, it might be supposed, of a bile-duct (fig. 6). They may be separated by a small space, which might be mistaken for the lumen of the bile-duct, although, in reality, it has simply been the line of separation between two adjacent rows of liver-cells. The dichotomous manner of division of the rows of liver-cells is still retained, so that the resemblance to bile-ducts is rendered more palpable. The bile-ducts, however, which are in natural proportion to the other tissues, can be easily distinguished from these, for, further than being slightly dilated and containing more epithelium than usual, they present no abnormal features. It frequently happens that several of these rows of nuclei are left in the midst of a cicatricial band, looking at first sight extremely like bile-ducts. No proper wall, however, can be detected in them, and if the individual cells be carefully examined, the remains of the hepatic-cell periplast can occasionally be detected.

This, however, is not the only arrangement which the liver-cell nuclei assume when set free. They are not always arranged in lines such as those just referred to, but are quite as commonly aggregated into irregular masses, or sometimes they lie singly among the cicatricial tissue. It is not difficult, under such circumstances, to make out that the free nuclei, previously described as being an abundant component of the cicatricial tissue, are in reality those liver-cell nuclei which have escaped by division or extrusion. When, therefore, we connect the two processes together, the setting free of the liver-cell nuclei and the subsequent evolution of these into fibrous

tissue, we establish a relationship between the liver parenchyma and white fibrous tissue, which, although not generally recognised, is, we shall see, quite in keeping with the process of cicatrization generally.

The absurdity of tracing the origin of the cirrhotic fibrous tissue to extruded blood leucocytes, as has been affirmed, but never demonstrated, by a certain school of pathologists, only requires for its detection a little unbiassed observation.

In summing up the foregoing remarks, the subjoined seems to be the chief—I will not say the exclusive—method of fibrous tissue formation in cirrhosis of the liver :—

(*a*) The liver cells are one of the main sources of the fibrous tissue developed in the organ.

(*b*) The first visible change in their transformation is the enlargement of the nucleus and the development of a nucleolus and intra-nuclear plexus (figs. 2, 3, and 4). The enlarged nucleus then divides (fig. 3), and this is almost simultaneously followed by transverse fission of the whole cell (fig. 4).

(*c*) Two smaller cells thus arise, each having a nucleus, and these nuclei soon grow to as large a size as that from which they sprung.

(*d*) The periplast, however, does not increase in size, *pari passu*, but at each successive division becomes smaller and smaller, until, finally, nothing but a free nucleus remains.

(*e*) This free nucleus now enters upon a new existence. It becomes oval, and from its border a fresh periplast is generated, which assumes a fusiform shape.

(*f*) The fusiform or spindle-shaped periplast now splits into a number of fibrils, and becomes more elongated and tapering at the extremities. The ultimate result is, the formation of a bundle of white fibrous tissue out of these fibrils, the nucleus remaining on the surface as the nucleus of the bundle.

These appearances, it must be remembered, are not met with in every instance of cirrhosis of the liver. It is only where an exacerbation of the disease has occurred that this active proliferation and organization can be observed. In most cases the organ is in a quiescent state at the time of death, and then the liver cells exhibit entirely different appearances, namely, those of atrophy from the pressure of the already formed fibrous

tissue. They are shrunken and shrivelled, and finally become resolved into masses of albuminoid granules, which are absorbed. The cicatricial tissue, during the periods of quiescence, loses many of its nuclei, and the fibrous tissue becomes much more organized. The spindled-shaped cells also in great part disappear, and the nuclei which remain become less susceptible to the action of colouring agents.

Two processes then are at work in the destruction of the liver cells: the one is of a constructive nature, the liver-cell nuclei multiplying and being converted into fibrous tissue; while the other has a destructive tendency, from the fact of its giving rise to their atrophy. The former occurs in exacerbations of the disease, the latter runs a much more chronic course, and takes place in the intervals of quiescence.

In my paper on the process of healing (this *Journal*, vol. xiii.), the statement was made that my observations had led me to the conclusion that the fibrous part of any cicatrix was always developed from a tissue derived from the middle layer of the embryo. The statement was made in full knowledge of the facts just related, regarding the transformation of liver cells into fibrous tissue. This naturally refers us to the origin of the liver cells in the embryo, which, even at the present day, seems to be still a matter of some uncertainty. The chief difficulty lies in making out whether the hypoblast forms merely the epithelial lining of the bile-ducts, or whether the liver cells are also developed from it. The first trace of the organ seems to be two sac-like processes, which are given off from the primitive duodenum. Around these a large mass of meso-blast gathers, in which a series of branching cylinders of cells are soon observed. These last are developed, in all probability, from the mesoblast, and are unconnected with the two hollow processes of the hypoblast given off from the duodenum. It is probable that they form the liver parenchyma. From the two diverticula arising from the duodenum offshoots can be seen passing into the future parenchyma, and these, there is good reason for believing, are the future bile-ducts. It would, therefore, appear that the epithelium of the bile-ducts is derived from the hypoblast, while the secreting parenchyma is a mesoblastic structure.

This entirely coincides with the character of the liver cell in adult life. It never is an epithelial-like structure, but has more the character of an endothelium. Its diseases are not like those of epithelium. It becomes fattily infiltrated like a connective tissue cell, and primary cancers do not arise in connection with it. The epithelium of the bile-ducts, however, has an entirely different character, and the diseases to which it is liable are exactly those of any other epithelial surface. It does not become fattily infiltrated, and primary cancerous tumours arise from it. The formation of fibrous tissue just described is another fact in favour of the essential embryological difference between the two, for, while the liver cells are a fertile source of fibrous development, the epithelium of the bile-ducts never seems to participate in this transformation. There is, therefore, nothing, in what has been made out in the foregoing observations, inconsistent with the statement that the fibrous part of any cicatrix is always derived from some tissue originating in the middle layer of the embryo. All that has been described goes to strengthen this view, and to show that there is a fundamental difference in the nature of the liver parenchyma and the epithelium of the bile-ducts.

Description of Plate VIII.

Fig. 1. Section of cirrhotic liver showing the general distribution of the nuclei × 50 diams—*a*, superficial layer of the capsule which is not thickened; *b*, deep layer very much thickened; *c,c,c*, the depressions on the surface; *d*, portion of hepatic parenchyma showing the large size and great number of the nuclei; *e*, section of a blood-vessel (hepatic artery), these are very numerous throughout the cicatricial tissue, and are mostly arteries and their dilated capillaries; *f*, a small isolated group of liver cells; *g*, the same in which the periplasts have been lost and the nuclei set free; *h*, part of hepatic parenchyma showing the continuity of the nuclei of the liver cells with those of the cicatrix.

Fig. 2. First stage in the proliferation of the liver cells. The nucleus has increased in size, and an intranuclear plexus has been developed. × 600 diams.

Fig. 3. Second stage in the proliferation of the liver cells. The enlarged nucleus has become dumb-bell shaped. × 600 diams.

Fig. 4. Third stage in the proliferation of the liver cells. The nucleus has divided, and a simultaneous division is taking place in the cell body. × 600 diams.

Fig. 5. Shows the elements of the cicatricial tissue (× 450 diams.)—*a*, fibrous bundle with nucleus upon it; *b*, spindle-shaped cell and nucleus; *c*, free nucleus with delicate periplast.

Fig. 6. Shows the reduction in size of the hepatic cells, the setting free of the nuclei, and the formation of these into rows. × 300 diams.

Fig. 7. Shows the transformation of the free nuclei into the spindles of the cicatricial tissue. × 300 diams.

CONTRIBUTIONS TO THE PATHOLOGY OF THE INTERNAL EAR. By P. M'Bride, M.B., C.M., M.R.C.P.E., *Pathological Laboratory, Edinburgh University.* (Plate IX.)

I. Croupous Inflammation of the Cochlea.

Of late years considerable light has been thrown upon the inflammatory affections of the labyrinth. That we may have a primary acute inflammation was rendered probable by the clinical experience of Voltolini, and has been verified, *post mortem*, by Schwartze. It is a well-known fact that inflammatory processes in the tympanum, both acute, as occurring in the exanthemata, and chronic, as the result of long standing catarrh of the middle ear, have a tendency to involve the labyrinth secondarily. A croupous inflammation of the cochlea, however, such as is about to be described, has not, so far as I know, been before observed.

The specimen was taken from a patient who died in the Royal Infirmary under the care of Professor Grainger Stewart, who kindly allowed me to make a dissection of the ear, and to describe the case. The facts are briefly as follows:—

The patient's condition pointed to an intracranial tumour, pressing upon the auditory and facial nerves among others, on the right side. The deafness had existed for a year before his admission to hospital, and facial palsy for a space of six months. The *post mortem* examination revealed a small round celled sarcoma, affecting the cerebellum and petrous portion of the temporal bone, pressing upon several of the cranial nerves, and sending a process into the internal auditory meatus.

No abnormal condition existing in the tympanum, the portion of the temporal bone outside of the promontory was removed. The internal auditory canal was then split up in order to ascertain to what extent it was penetrated by the growth, which was found to stop short of its fundus. In opening the meatus auditorius internus the split was carried through the vestibule, thus separating two portions of bone, the one of which held the

cochlea while the other contained the semi-circular canals. The vestibule itself, as far as could be judged by the naked eye, was normal. Each portion of bone was then reduced in size as much as was compatible with the safety of the structures in its interior, prepared for histological examination, and finally cut into sections.

When those of the cochlea were examined, as they floated in water, part of the lumen of the cochlear tube was seen to be filled by a faintly yellow substance. Before going further I would refer the reader to fig. 1, which was drawn from a section (magnified 50 diameters), which shows well most of the points of pathological interest.

Microscopical examination of the sections under the low power (× 50 diam.) showed that the foreign body before mentioned occupied a considerable part of the scala vestibuli, in some even three quarters of its lumen. Under this magnifying power it seemed to be composed of delicate straight fibres, interlacing in various directions, and inclosing in their meshes small cellular bodies. The great bulk of the material lay in the part of the scala, away from the membrane of Reissner, but in some specimens that membrane itself was seen to be thickened and infiltrated with the same fibrillar structure. Certain spaces of the modiolus lying near the lamina spiralis ossea were also seen to be filled with the same delicate substance. In the scala tympani in most preparations a small quantity of granular looking matter was found, generally lying on or very near the periosteum, but differing altogether from that found in the scala vestibuli. Under a higher magnifying power the foreign matter in the scala vestibuli, membrane of Reissner, and bony spaces of the modiolus, was seen to consist of delicate transparent fibres interlacing for the most part at acute angles. Most of these fibres were straight (although one or two were slightly curved) and presented the appearance of a transparent centre bounded by two darker lines. At some parts they were more numerous than at others, and then they combined to form a stellate appearance as is represented in fig. 2. Entangled in the meshes of this network we can see some leucocytes, the interior of which is granular, and in some cases showed vacuoles. In all respects the microscopic appearances correspond to those

of fibrinous lymph as seen in acute inflammatory affections of other organs.

The material above mentioned as lying in the scala tympani, when viewed with the high power, is only seen to be more coarsely granular than before, but no light is thrown on its origin. It may possibly be degenerated fibrin.

The periosteum of both scalæ (more especially the scala vestibuli) is much thickened, infiltrated with fibrin and leucocytes, and traversed by numerous dilated vessels, which are visible even under the low power. In some places it is loosened from the bone, and in most parts its epithelial lining seems to have been lost. The spiral ligament, too, in several specimens, was seen to contain dilated and tortuous vessels and to be loosened from its bony attachment. This hyperæmic condition was also present in the bone surrounding the cochlea and in the modiolus. In the latter situation especially, sections of large vessels were seen, contained in bony spaces and surrounded by exuded leucocytes. The bone in the neighbourhood of the cochlea showed distinct signs of sarcomatous infiltration. In some preparations large masses of small round cells were found in the bone. These cells, when compared with cells from the original tumour, were seen to be identical in structure. The sarcomatous infiltration in all probably occurred through the cochlear branch of the internal auditory artery.

When we consider the extensive changes which had taken place in the other parts of the cochlea, it is surprising to find how little the parts contained in the cochlear duct suffered.

By a study of two or three of the best sections a very perfect picture of the organ of Corti and its adjacent parts could be obtained. The membrana tectoria was seen floating freely from its attachment to the vestibular lip of the crista spiralis, and displaying its characteristic delicately striated structure. The latter (crista spiralis), too, was well preserved, and those curious bodies called the auditory teeth by Huschke could be seen. They are shaped like the incisors of a rabbit, and are said by Hensen to be modified epithelial cells. The junction of the external and internal pillars of Corti could be distinctly seen, and one or two hair cells were also visible. The membrana reticularis, too, could be distinguished.

The semicircular canals were examined, but not a trace of fibrin could be found in them. Possibly in this case the deafness was at first due to inflammation of the cochlea, and not to direct pressure on the auditory nerve; otherwise it is difficult to account for the long interval that elapsed between the onset of the deafness and that of the facial palsy. Should this view be correct, it is possible that a sarcomatous tumour not directly involving the auditory nerve might, by extension along the internal auditory artery, set up a cochleitis, and with it, of course, complete nervous deafness, as indicated by the tuning-fork, but without facial palsy.

Burnet, in his treatise on the ear (p. 586), gives an account of the examination of the internal ear in a case of cerebral tumour not unlike the one here described. He, too, found a foreign substance in the scalæ, but unfortunately minute details of its microscopic structure are not given.

II. An Abnormal Condition of the Semicircular Canals.

The condition of the semicircular canals about to be described occurred in the case of a patient (an adult) who died of acute rheumatism, and while taking the salicylate of soda. Deafness and ringing in the ears came on while this remedy was being administered, and the internal ear of one side was examined to ascertain if this drug produces deafness through producing an organic change in the labyrinth. The method of examination was conducted in the same way as in the previous case. Microscopic sections of the cochlea revealed no deviation from the normal, but sections of the semicircular canals showed a state of things quite different from that usually found, a condition, however, which could not have been due to the salicylate of soda.

The normal appearance of a section through a bony and membranous canal shows the lumen of the bony portion to be oval in shape and lined by a periosteum. Lying in this bony canal, and touching the periosteum at one point, is the membranous canal, which is also oval in shape, but the lumen of which is very much smaller than that of its containing bony tube. This membranous canal is held *in situ* by the ligaments of the semicircular canals, which, roughly speaking, fill up the angles formed by the divergence of the membranous and bony tubes.

By far the greater portion of the lumen of the osseous canal is seen to be empty, but traversed by one or two bundles of connective tissue which support blood-vessels. The wall of the membranous canal itself consists of four layers: (1) an outer layer of connective tissue; (2) a homogeneous layer; (3) a layer of papillæ, which, however, are not present on all parts of the canal; (4) a layer of epithelium, lining the canal. This is the description given by Rüdinger of the anatomy of the parts under consideration, and the main points of it I have been able to verify from preparations now in my possession.

The specimen under consideration, however, presented a very different state of things. On examining one of the sections with the low power, the shape of the osseous canal was found to be not oval, but to present an angle at one point as shown in the accompanying figure 3. Inside of this was the membranous canal, having at some points well-marked papillæ. The membranous tube was, however, at no part in direct contact with the periosteum, though much nearer it at some points than at others. Stretching between the outer layer of the membranous canal and the periosteum lining its bony cavity at all parts, was a delicate reticular tissue, traversed here and there by coarser fibrous bands, and at parts showing cut vessels. Examination with the high power revealed that the tissue filling up the perilymphatic space was composed of bundles of fibres of various thickness, starting from the outer (connective tissue layer) of the membranous canal on the one hand, and from the periosteum of the osseous wall on the other, and interlacing in all directions. On and alongside of the bundles were seen connective tissue nuclei. In some parts the different layers of the membranous canal are beautifully seen (see fig. 4). The outer connective tissue layer is seen containing many nuclei; at one part the homogeneous layer is very distinct, and inside of that again are the papillæ. On one of these rounded papillæ are seen three nuclear bodies. In all probability these are the nuclei of epithelial cells, the outline of which cannot be distinguished.

In the embryo, according to Rüdinger, the whole of the space between the membranous and bony canals is filled with myxomatous tissue (Gallertgewebe), and from this are developed the ligaments of the canals and the fibrous supports of the blood-

vessels. In the case before us it seems probable that the abnormal condition depended upon a very much larger quantity of this myxomatous matter becoming organised into fibrous tissue than is usually the case. In the rat the space is normally filled with reticular tissue.

In conclusion, I beg to express my thanks to Dr Hamilton for his kindness and assistance, especially in doing one of the drawings (fig. 4) for me.

Explanation of Plate IX.

Fig. 1. Section through cochlea, showing fibrinous lymph in the scala vestibuli (× 50)—*a*, modiolus; *b*, bone surrounding the cochlea; *c*, periosteum lining the scala tympani (much thickened and showing dilated vessels); *d*, basilar membrane twisted on itself and concealing the spiral ligament; *e*, membrana tectoria, showing delicate striæ; *f*, membrane of Reissner, also twisted on itself, much thickened and infiltrated with fibrin; *g*, fibrin filling up greater portion of the scala vestibuli; *h*, dilated vessel contained in one of the spaces of the modiolus; *i*, cut nerves in the modiolus; *j*, lamina spiralis ossea, showing a darker portion in its centre, viz., the branch of the cochlear nerve which runs along it; *k*, granular substance lying in the scala tympani.

Fig. 2. Showing fibrinous lymph (× 300)—*a*, fibrin, with its characteristic structure; *b*, leucocytes entangled in its meshes.

Fig. 3. Showing transverse section of an abnormal semicircular canal (× 50)—*a*, periosteum lining the bony canal; *b*, wall of the membranous canal; *c*, reticular tissue filling up the space between the bony and membranous canals; *d*, coarser bundles of fibrous tissue; *e*, section through blood-vessels; *f*, papillæ on the inner wall of the membranous canal.

Fig. 4. Reticular tissue and wall of the membranous canal more highly magnified (× 300)—*a*, interlacing bundles of fibrous tissue enclosing spaces of different size; *b*, nuclei lying on the fibrous bundles; *c*, sections of blood-vessels; *d*, external or connective tissue layer of the wall of the membranous canal; *e*, small portion of the homogeneous or middle layer; *f*, papillæ—on one of them are seen three round bodies, which are probably the nuclei of epithelial cells covering the papillæ.

ON A NEW BONE IN HUMAN ANATOMY, TOGETHER WITH AN INVESTIGATION INTO THE MORPHOLOGICAL SIGNIFICANCE OF THE SO-CALLED INTERNAL LATERAL LIGAMENT OF THE HUMAN LOWER JAW. By SAMUEL G. SHATTOCK.

THE skeleton which is the subject of this anomaly is interesting, both from a pathological and an anatomical point of view; but its greater interest lies in that which relates to its morphology, rather than in what it illustrates of pathology. In regard to the latter, it exhibits the changes which occur in the bones in rickets, although the skeleton of a fœtus, and this in so marked a degree, that it would be difficult to find the changes more advanced in any case in which the disease has appeared, as it almost invariably does, after birth. The rachitic changes are perhaps of syphilitic origin; and the morphological anomaly is probably related to the disease, as I will afterwards notice. I may first describe the parts concerned, and then draw the plain homologies.

The auditory ossicles are fully ossified, the tympanic bone well developed. That portion of Meckel's cartilage which suspends the lower jaw has undergone complete ossification, and forms a cylindrical process of bone continuous with the malleus, and passing from the tympanum between the tympanic ring (which is boldly arched over it) and the spinous process of the sphenoid bone. The manubrium of the malleus is not of lesser size than natural, whilst the opposite process, in place of being more slender, is fairly twice as thick. The distal extremity of the unnatural process is slightly enlarged, so as to make the whole somewhat club-shaped. This abnormal process, however, does not itself abut against the lower jaw; the two are connected by a short, flattened, pointed, or spatulate bone, of which the distal and the larger end is articulated (apparently by continuity) with the enlarged extremity of the "processus gracilis," whilst the other end is articulated with the spine, which overtops the anterior margin of the dental canal; this articulation also appears to have been one of continuity, either by cartilage or fibrous tissue. Thus, on either side, between the

lower jaw and the malleus, is a bone, though small, yet quite distinct, of definite form, equal on the two sides, and symmetrically evolved.

The homologies present little difficulty. The malleus, with its longer portion prolonged towards the mandible, being taken as the quadrate of birds and reptiles, the little element intercalated between this and the dentary will be the os articulare.

The rest of the cartilaginous arch, or that round which the membranous growth of the jaw proceeds, has, as usual, formed anteriorly from its enlarged extremity, the triangular block of bone which underlies the incisor teeth;[1] but throughout the rest of its extent the cartilage of the arch has been in process of ossification, as evidenced in the filling in, in places, of the groove which it naturally fills.

The formation of bone in these several unnatural positions, is, probably, to be associated with the effects of the disease. For the production of bone in excessive amount, and of immature structure and hardness, is the gross result of rickets, as it is localized in the parts of the skeleton. Thus, in the specimen under notice, the production of unhealthy bone has proceeded both in and around the substance of the costal cartilages, which never happens in children, though true bone may at times be found in the costal cartilages of comparatively young adults.

But the interest lies in the definite result of the ossification in that portion of Meckel's cartilage which naturally almost wholly disappears, since, long before the time of adult life, the only osseous remnant of this suspensory portion of the arch does not exceed the limits of the Glasserian fissure. The unnatural ossification being called forth, it has proceeded in conformity with a type, and produced a quadrate bone and an os articulare.

In the adult, the malleus, with its slender process prolonged towards the mandible, represents the quadrate. Is there any permanent representative of the original suspensorium between this and the lower jaw?

In the arch next below, the stylo-hyoid ligament, which connects the corniculum of the hyoid bone with the styloid process, is formed in connection with the slender cartilage which first

[1] George W. Callender, *Philosophical Transactions*, 1869, p. 163.

marks its position, and it maintains the hyoidean arch throughout life, though the prime constituent of the arch no longer persists. In regard to the mandibular arch, it is submitted that the portion hitherto regarded in man as lost, remains permanently represented by the structure often known as the internal lateral ligament of the lower jaw,—the band of fibrous tissue which passes between the sharp spinous inner margin of the dental foramen and the spine of the sphenoid bone,—a structure which forms no integral part of the articulation, and to which no function has been assigned. Between the fourth and fifth month of fœtal life, the connection of this ligament with the suspensory portion of Meckel's cartilage is readily discernible, and remains so as long as any of the Meckelian cartilage persists, the relation of the two being observable almost to the period of timely birth.

On dissecting the parts from the inner side, the slender arch of cartilage is visible, lying against the lower jaw, in the posterior two-thirds of its extent immediately beneath the attachment of the mylo-hyoid muscle, beyond the free border of which muscle it is concealed between the jaw and the internal pterygoid. On dividing the inner pterygoid, the cartilage is traceable upwards to the inner side of, and behind, the dental foramen, and beyond the dental foramen, unconnected with bone, to the base of the skull, where it enters the tympanic space as a permanent component of the malleus,

Such a dissection will display, also, the internal lateral ligament, attached to the entire breadth of the inner margin of the dental foramen, having a well-defined falciform anterior margin, and including the cartilage of Meckel in its posterior part; the two are, indeed, intimately connected, the cartilage being wrapped up in the fibrous tissue of the ligament. Traced upwards, the ligament becomes considerably narrowed, and is fixed by its upper end to the spinous process of the sphenoid bone and parts in its immediate neighbourhood, whilst the portion of the cartilage beyond is united by fibrous tissue to the edges of the fissure by which it enters the tympanum.

A consideration of the development of the lower jaw confirms, also, the association of this ligament with the cartilage of the mandibular arch.

In the earlier stages of ossification of the lower jaw, Mr Callender describes the growth of a horizontal ridge of bone in connection with the upper surface of the Meckelian cartilage, this ridge separating the cartilage from the dental nerve. The projecting ledge, at first convex superiorly, becomes subsequently concave, and curls over the nerve, so as to complete the dental canal.

Now the lower edge of the internal lateral ligament is attached to the posterior margin of the bony ridge which, when com-completed, forms the dental canal.

It will follow, therefore, that the growth of this bony ridge and the formation of the ligament must proceed simultaneously; both are formed in connection with the Meckelian cartilage, as are the stylo-hyoid ligament and the corniculum in connection with the cartilage of the arch next succeeding.

The inner margin of the dental foramen is almost invariably overtopped by a sharp spine of bone, which, as is evident from its apposition with the articular element in the anomalous specimen first noticed, is formed in immediate connection with the Meckelian cartilage, of which it may be considered as the extremest bony product continued in the line of the original arch.

In no long time after birth, the remnant of cartilage between the dentary and base of the skull included in the ligament doubtless disappears, as does that which is long previously replaced by the stylo-hyoid ligament in the succeeding arch. Yet the fibrous tissue remains in the precise position of the suspending cartilage, still connecting the dentary with the skull, and permanently maintaining the completeness of the original arch.

The morphological significance of the ligament might be marked by naming it simply the suspensorium.

ON THE DISEASE CALLED STURDY IN SHEEP, IN ITS RELATION TO CEREBRAL LOCALISATION. By GEORGE T. BEATSON, B.A. (Cantab.), M.D. (Edin).[1]

IN the present paper I desire to direct attention to a subject which appears to me to be of some interest, inasmuch as it bears on a question which has recently excited a good deal of discussion, and can hardly yet be regarded as settled. I refer to the Localisation of Brain Functions. The investigations and experiments which have been performed with a view of establishing this theory, leave no doubt as to the existence of "active spots" on the surface of the cerebral hemispheres, but what these "active spots" imply, and what interpretation is to be put on the phenomena they give rise to, is still a controverted point. This unsettled state of the matter is in no small measure due to the disturbing influences introduced by the present methods of investigation. Accordingly, any facts that will throw light on the subject, or that will suggest a more suitable line of investigation than any of those at present employed, is worthy of consideration. It is this feeling that has prompted me to bring briefly under notice a malady which occurs in one of our chief sources of food supply, and which has connected with it so many physiological and pathological facts of interest, that I regard it as deserving of more consideration than it has hitherto received. The disease itself is well known and fully understood, and this paper is not written with any view of throwing further light on it; but no suggestions have as yet, I think, been thrown out as to the possibility of making it available for the elucidations of points connected with the physiology of the nervous system, and it is with this object that I offer the following remarks. I will first sketch in outline the disease, give some cases to illustrate it, and then state the thoughts that have occurred to me as entitling it to a more extended study, especially at the present time, when the efforts of misguided popular enthusiasm have in this country

[1] This paper was part of a thesis sent in for the degree of M.D. of the University of Edinburgh. It was accompanied by specimens taken from the cases referred to in the paper.

confined the field of experimental inquiry to the privileged few.

My attention was drawn to the malady by observing one day a sheep affected with a peculiar rotatory movement, which I was told was due to "a bag in its head." I was aware of these "circus movements" occurring in animals that had been made the subject of physiological experiments, but I did not at that time know that they occurred in the course of any disease. My interest in the matter in a few days was still further aroused by seeing a sheep, similarly affected, operated on by plunging a trocar into a softened spot in the animal's skull, when a quantity of clear fluid was withdrawn. Relief of the symptoms at once followed, but I had my misgivings as to the ultimate success of the operation, as the trocar used was neither visibly, nor, in these days of germs, invisibly clean, and the operation had little of the *suaviter in modo* about it. The result was as I had anticipated. In four days the animal became generally convulsed, and died. I obtained leave to open the head, and found the membranes in a state of inflammation, and one hemisphere occupied by a cyst, the contents of which were purulent and putrid, and very different from the clear fluid I had seen evacuated a few days previously. The hemisphere involved was invaded to an extent I had not at all anticipated, being reduced to a mere thin layer of nervous matter covering the cyst. I had seen the animal during life, and beyond the rotatory movement mentioned, there seemed no great impairment of motor power. I was in this way led to look further into the subject, and, as the result of my reading and observation of some other cases that came under my notice, I gathered the following facts.

The disease is by no means an uncommon one, and is known by various names, such as sturdy and turnsick, but its essential character consists in the presence in the brain of the sheep of an hydatid, the cænurus cerebralis, which is a cystic or bladder worm, and is the larval stage of the tænia cænurus, one of the six varieties of tape-worm which infest the dog.

It was not until 1853 that the cause of sturdy was known, and up to that time many curious reasons were assigned for it. In the year 1853, however, Kuchenmeister showed conclusively that these cysts in the brain were hydatids, and that they were

the larval stage of the tænia cænurus of the dog. His experiments consisted in giving to dogs these hydatids from the brains of sturdy sheep. As a result of this they became affected with tænia cænurus. He then fed lambs on the joints of the tænia thus obtained, and in little more than a fortnight he found the symptoms of sturdy made their appearance. At the suggestion of Kuchenmeister others pursued the line of inquiry, and with similar results. The only experiments that I shall mention are those of Dr Haubner of Dresden, who fed six young lambs on the segments of a tænia cænurus. They all died of sturdy, and the cænurus cysts were found in the brain, and in other organs of the body, as the lungs, heart, and voluntary, but in these latter situations they seemed to be abortive, and only to flourish in the brain, where, in the *cortical* substance of that organ they were found in different stages of development. The symptoms of the vertiginous disease commenced in about a fortnight after the administration of the segments of the tænia; and indeed it was noticed in all the experiments that the appearance of the symptoms was curiously constant, ranging from the fifteenth to the eighteenth day.

The establishment of the connection between the hydatid in the sheep's brain and the tænia of the dog soon cleared up many points connected with the disease that were difficult to explain. Thus, it had been observed that sheep in the lowlands were not so much affected as those fed on the higher regions, and various theories were put forward to account for it; but it is to be explained by the fact, that on the lowlands the sheep are usually kept in enclosures, and no dogs are required, while on the more elevated parts dogs are of necessity needed in tending the sheep, and are thus brought into contact with them, and set up the disease. If we take the case of a dog affected with tænia cænurus, it is not difficult to trace the course of events. He wanders about distributing the ova of the tænia on the pastures, and they are scattered by various other agencies, and are swallowed by the sheep while grazing. When they have reached the true digestive stomach they are acted on by the gastric juice, their coverings are dissolved, and the small six-hooked embryos escape, and by means of their hooks bore their way into the blood-vessels, and are carried to the brain, where they take up

their abode, either from some selective power on their own part, or favoured by the peculiar cerebral circulation in the brain of the sheep, with its wonderful *rete mirabile.* When they have reached the brain they once more make their way out of the blood-vessels, and undergo changes adapted to their new and final resting-place. Thus, they part with their hooks and gradually acquire the bladder-worm state, in which condition they vary in size from a pin's head to a walnut. After a further period of some weeks they attain their polycephalous condition, and thus complete what we must regard as a most wonderful cycle of changes in development.

In its polycephalous condition the hydatid is a thin transparent bag or cyst with a number of small whitish spots like eggs on its surface, disposed in regular lines. These are the heads of the hydatids, and they possess the peculiar property of being *exsertile* or *protrusible,* a characteristic of some importance, and which bears on some of the symptoms of the disease. The fluid contained in this cyst is of a clear pellucid character. It has a sp. gr. of 1·008 to 1·013, and it is either neutral or slightly alkaline. It has only a trace of albumen, but it has some extractive matters and some salts, chiefly the chloride of sodium. The cyst wall consists of two layers, an ectocyst which is fibrous in character, and an endocyst, which is a very thin and delicate membrane. The latter is the mother sac of the embryo (Huxley) and corresponds to the germinal membrane of Goodsir. It is the seat of development of the heads of the hydatid, and to it they are attached. Examined microscopically one of these heads appears in the form of a tetragon with a circle of sickle-shaped hooklets at its summit, and a mouth on each of the sides of the head. A single cyst may support a number of these heads, the number depending on the age of the cœnurus. The cyst is not incorporated with the brain substance, but is surrounded with areolar tissue and can be readily removed. In fact, in making *post mortem* examinations on sturdy sheep, if the head was at all turned over and the cyst on the surface of the brain it would fall out from the bed in which it lay. One other point connected with the life history of this hydatid demands notice. It is this, that after a variable time it causes a softening of the skull at one spot, the bony roof of the cranium disappearing by

the constant pressure of the cyst, and the presence of this soft and yielding spot forms a guide to the situation of the hydatid It may be possible that pressure is not the only factor in causing this absorption of the bony wall of the skull, but that it is partly due to the protusible heads of the hydatid, which not only remove the brain substance but eat away the bone itself, which sometimes presents in its interior a worm-eaten aspect.

Coming next to the symptoms developed by the presence of the hydatid in the brain of the sheep, we find that they vary with the stage that the disease has reached, but they are such as to be of great interest to the physiologist. Amongst the earliest symptoms of the disease are those of cerebral congestion, as shown by the red eyes and dilated pupils, and this is followed by an inclination on the part of the animal to separate itself from the rest of the flock. It becomes dull and listless about its food, and often seems filled with an imaginary nervousness and dread. Often these symptoms subside as the brain becomes absorbed and the contents of the skull adapt themselves to the new parasite, but it is usually a temporary improvment, and the symptoms increase in severity. Thus the head turns to one side, there is difficulty in grazing, the animal becomes frightened without any apparent cause, and it likes to stand over any running water, as if the murmuring sound caused by it had some soothing influence over it. Sooner or later appears the rotatory movement which is characteristic of the disease. It is a very peculiar movement, and I will not discuss it further here, than by stating that its direction is influenced by the situation of the cyst in the brain. Thus, if it is in one of the hemispheres the animal turns to that side; while, if it is in the cerebellum, there is a peculiar uncertainty of gait and a reeling motion. When once the rotatory movement is developed, it increases in frequency and rapidity, interfering with the animal feeding, and eventually it leads to its death by exhaustion and emaciation.

Of the treatment usually adopted in this affection I do not propose to dwell at any length, beyond stating that the plan now chiefly in vogue of removing the cyst, as soon as softening of the skull declares its whereabouts, seems the most rational course. It is founded on the natural cure of sturdy, which is

sometimes seen in cases where the affected sheep receives a wound at the point of the skull where the bone has been thinned or absorbed. Through the aperture thus made the hydatid escapes, favoured by the fact that the cyst is surrounded by areolar tissue and is not incorporated with the brain substance. It is as well, if the symptoms allow, to wait for the softening of the cranial bones, as it does away with the necessity for the trephine, and thus avoids a large opening into the skull. Even this instrument, however, is used with success; and I find that Sir Astley Cooper, who was much attached to the veterinary art, and conducted many interesting experiments at his farm near Hemel Hampstead, used to take great pride in exhibiting an ewe which he had trephined for sturdy, and from whose cranium he had extracted a large hydatid.

Did space allow I should like to say a few words in reference to the descriptive anatomy of the sheep's brain, but I will content myself with alluding only to the convolutions and to the vascular supply. As regards the former, when we examine a sheep's brain we are struck with their very sinuous and tortuous character, but they are symmetrical on both sides, and are not unlike in some respects to those of the human brain. On taking a side view of the brain the well-marked fissure of Sylvius strikes our eye, and we notice that the convolutions have a tendency to group themselves round it, although they really traverse the whole brain from before backwards. In the cerebral circulation the chief point to be noticed is the existence of a well-marked rete mirabile, which is made of two lateral elongated lobes, almost independent of each other, but each forming a small ovoid mass, elongated from before backwards, and lying on each side of the sella turcica beneath the dura mater. This rete is composed of a multitude of fine arterial twigs which anastomose with each other very freely, and, doubtless, the object of it is to moderate the rapidity of the blood current as it enters the cranium in the different positions of the head, and thus preserve the brain from any sudden influx of blood to which it might be exposed by the head of the animal assuming the dependent position. Besides furnishing in this way an equable supply of blood without the risk of check or hindrance, it obviates the tendency to any congestion of the brain while

the animal is feeding. There is also in the course of the ophthalmic artery an arterial plexus very similar to the rete. While, however, these peculiarities in the blood supply of the brain of the sheep have a salutary tendency, they also favour the disease of which I write, for we have seen that the hydatid enters the blood-vessels and is carried along in the circulation. Hence the vascularity of the brain, the slowing of the blood-current in the rete, and the thinness of the walls of the capillaries are all in favour of the parasite choosing the brain as its habitat.

I have now sketched in outline the essential characters of the affection under discussion, and I now purpose to allude briefly to some cases that I had under observation, and the course and nature of which exemplify several of the points that I am inclined to think make this malady somewhat more deserving of general notice.

One of the first cases of sturdy that came under my notice was that of a sheep affected with muscular tremors of the body, together with difficulty of locomotion, and it was considered by the owner to be suffering from a disease called "the tremblings." Whatever was the pathological condition in the case, it was evident that there was a decided loss of co-ordinating power, as shown by the unsteady gait, and by the fact that, as soon as the animal was urged to move faster than the ordinary walking pace, it fell on its left side and was unable to rise. When it was killed I obtained the head, and on examining it I found in the cerebellum an hydatid, which had destroyed a greater part of the left portion of the central lobe, and also part of the left lateral lobe. There was only a thin layer of brain tissue covering the cyst. The rest of the brain was healthy.

This case was of interest to me as confirming the generally received view,—established by experiment, pathological evidence, and comparative anatomy,—that the cerebellum is concerned in the co-ordination of movement. As to the exact manner in which it exercises this function there may be a difference of opinion; but it is probably from its connection with the restiform bodies and the corpora quadrigimina, the former conducting the impressions belonging to the muscular sense, and the latter the guidance furnished by the visual organs. But this case further

suggested to me the question, Whether we have not in this malady a means of investigating brain function that has something to recommend it? It would only be necessary to obtain a number of sheep or lambs, feed them on the segments of the tænia cænurus, and we would have developed in them, perhaps, this very lesion, or some other one of equal interest. I know that there is much to be urged against the results given by disease, or, as they are sometimes termed, "nature's experiments"; but there are also weighty objections to the present methods of experimental inquiry, for often the symptoms must be attributed to the operation itself, with its shock, hæmorrhage, and subsequent inflammation. All these latter disturbing elements are absent in the method I propose. It is true that we cannot fix definitely beforehand the lesion we will have, but the experiments of Dr Haubner and others make it clear that we may reckon on some lesion being established in the cortical substance of the brain, and that within a comparatively short time, for we saw that in those cases the symptoms of sturdy declared themselves in about fifteen days. I am also inclined to think that investigations such as these do not come within the pale of the law as it at present stands,—and that is no small recommendation at the present time, when popular ignorance and prejudice has done so much to limit scientific inquiry. The structure, too, of these hydatids, with their protrusible heads, is a point not to be lost sight of, for owing to this they are real cerebral excitants, and at the same time remove, little by little, the brain substance in their vicinity, so that they would be classed under the head of investigations by local destruction. It will be seen, also, in connection with some of the cases I shall quote, that by this disease parts of the brain are destroyed which it is very difficult to reach experimentally, except by very complicated and severe measures, and also that much of interest may be learnt by the removal of the cyst after definite symptoms have shown themselves. These reasons have weighed with me in thinking that there is a good deal to recommend the method of investigating the functions of the brain, by inducing disease in it by means of ova which have a predilection for that organ, especially as they take up their habitat in the cortical substance of the brain, the tissue in

which recent inquiries have located nearly all the "centres" of our daily life.

The next case that I shall allude to was affected only with the symptom of the rotatory motion to which reference has been made, as being so characteristic of sturdy. The animal was able to graze, and suffered not the slightest loss of motor power, but at intervals it exhibited a single rotatory movement, which took place from right to left, *i.e.*, the creature turned its head towards its own right, and executed a "circus movement" round about the spot where it stood. I forced it to run, when it did so quite well, but every now and again it would perform this rotatory movement on its own axis, and then continue its course in a straight line. This was the only objective symptom I could detect. In every other respect the creature was active and well-nourished. I made a *post mortem* examination of the head. On taking off the calvarium, nothing abnormal was noticed; but when the brain was entirely removed, I observed that the lower part of the right hemisphere was occupied by a cyst. A further examination of the brain, after it had been hardened in spirit and the cyst removed, showed the following lesions:—There was a cavity in the right hemisphere of the size of a pigeon's egg. Looking at the brain from the outside, it was seen that the external root of the olfactory lobe was destroyed, as well as the extra-ventricular portion of the corpus striatum, which was reduced to a thin transparent layer of nerve tissue. An examination of the interior of the cavity made by the cyst showed that the corpus striatum had entirely disappeared, as well as the tænia semicircularis with its covering of the choroid plexus, and also the anterior part of the optic thalamus.

In connection with this case, the only point I wish to consider is the rotatory movement, although the case also presents one other point of no small interest—the gradual disappearance of the corpus striatum without loss of motor power. As regards the rotatory movement, it is not clear why it should be so marked a symptom of sturdy. Some think that it is due to the exsertile power possessed by the heads of the hydatid, which can penetrate the brain substance to the depth of nearly two lines, and thus really become cerebral irritants. One writer regards the turning as a phenomenon of excitation, and, com-

paring the exsertile heads of the cænurus to pin points, he asks if very manifest phenomena of excitation would not result in any animal, by plunging into the substance of the brain a great number of pin points at a depth varying from one to two lines. He also thinks that the increase in the number of the heads, as the cænurus assumes the polycephalous condition, explains the increase in the number and frequency of the rotatory movements. I am myself inclined to look on these movements as the result of irritation, which interferes with the proper working of the general co-ordinating mechanism of the brain, irrespective of the structure involved. If this be the correct interpretation of the phenomenon, it throws light on the occurrence of such movements after experiments on the brain, for it is well known that they follow very different operations, and Brown Sequard has tabulated a number of the injuries that cause them, showing that they are confined to no particular structure. At first I was inclined to attribute them, in the present case, to the involvement of the ganglia at the base of the brain; but subsequent cases, where these ganglia were intact and where the movements were present, forced me to relinquish that idea, and rather to fall back on the irritant element present in the disease. I regard, then, this disease as valuable to the physiologist, in showing that many of the symptoms that follow an experimental operation may be due, not to the lesion of any particular part of the brain, but to the general influence which the operation has set up in the delicate and sensitive apparatus of the nervous system. This influence that I speak of acts either by making the brain unable to receive the many afferent impulses which are continually making themselves felt, or by rendering it incapable of putting forth the controlling power which we call the Will. We know how, in the normal state, every minute of our lives, influences from sight, hearing, muscular sense, and other sources invade our frame, and how necessary they are for our movements, and how completely they are under our will. Bearing this in mind, and remembering that in animals, lower in the scale than man, any interference with the sources from which these guiding influences come makes itself still more felt, we can understand how an irritation that exercises an inhibitory action over the will or the different senses will allow of such

movements. The question then is, whether we have evidence in this disease of inhibitory action over any of the senses by which guiding influences come. I think there is. Struck by the fact that, in the present case, the cyst was on the same side as the rotatory movement, I examined as carefully as I could into the condition of the sight in all the cases of sturdy under my notice, and I invariably found that when the vertiginous movement was present, there was some interference with vision on the opposite side of the body, though, as the disease advanced, both eyes might become involved. Accordingly, I am inclined to think that, while the actual rotatory movement is due to the irritation of the cyst setting in action nervous force which is too strong for the now weakened will to control, the direction of the movement is determined by the fact of the visual power being in abeyance. Undoubtedly sight is a powerful factor in the co-ordination of our movements. As Mayo long since observed: "We lean on our eyesight as on crutches;" and, if further confirmation of the remark were needed, we have only to refer to the experiments of Flourens and Longet, the former of whom produced vertiginous movements in pigeons by blinding one eye, and the latter by evacuating the humours of the eye. This view as to the origin of these rotatory movements derives support from the fact that, when sturdy becomes far advanced, and the vision of both eyes is affected, the vertiginous movements cease. It is also in keeping with the statement furnished by persons who suffer from similar movements, that they are usually preceded by some disorder of the sight. On these grounds I do not support the theory that explains these movements as due to spasms and paralysis of the muscles on the side towards which the movement takes place, for my experience has been that they always occur on the side corresponding to that on which the cyst is. Now, if the brain lesion affected the muscles at all, it would do so on the opposite side of the body, and hence the rotatory movement should be on the side opposite to that on which the cyst lies.

The next case to which reference will be made illustrates the point that impressed me so much in the first case of this disease which I saw, namely, the extent to which a cerebral hemisphere may be destroyed, and yet there be no loss of

motor power. In this instance there was in the left hemisphere a cavity which held 6 drachms of fluid, and the region round the Sylvian fissure, corresponding to Ferrier's motor region, and in which all his motor centres lie grouped, was reduced to a transparent layer of tissue, no longer fit to be considered capable of discharging its functions, and microscopically showing no trace of nerve structure. Notwithstanding, there was an entire absence of paralysis, the only symptoms noticed being turning of the head to the left side while standing and eating, and well-marked loss of vision in the right eye. Under circumstances such as this, it is not strange, I think, that one should feel some doubt and suspicion, not as to Ferrier's facts, but as to the conclusions he draws from them. Because electrical irritation of certain spots on the surface of the brain calls forth movements, he considers that the spots are the motor centres of that organ, not only in the sense that they are the areas to which motor influences come, and from which motor influences descend to the parts below, but also as the regions where the processes of thought involved in these movements take place. If such is the case, it is hard to understand how the animal, in the case I refer to, was able to make a complete and co-ordinated movement to escape, as it did when I tried to catch it in the field. It should have lain a struggling paralytic, one side of its body in full possession of motor power, the other devoid of motion and a hindrance to progression. When we see an animal capable of putting into execution a movement which involves volition and motor power, then we are, I think, at liberty to conclude that its psycho-motor centres are not absent, and if the only region where they are said to exist is destroyed, we are surely warranted in concluding that that region has had powers assigned to it which it does not possess, or which are shared by other parts as well.

Did space allow, I should much like to speak of two cases of sturdy in which there existed well-marked and defined lesions of the hippocampal region without paralysis or loss of motor power of any kind, though Ferrier has assigned these consequences to destructive lesions of those parts of the brain. In one of them, in which the whole of the posterior lobe of the left hemisphere was destroyed and the convolution correspond-

ing to the gyrus fornicatus of the monkey was reduced to a mere layer of disintegrated nerve tissue, the creature was active and brisk, suffering only from a rotatory movement from left to right, and from some impairment of vision in the right eye. This latter defect showed itself to me one day while I was trying to catch the animal to examine the state of its pupils. It made off across the field at a very quick pace, and, while running, it passed a tree from which it shied away, exactly as a horse does from an object that it cannot quite make out. From this occurrence I was led to regard its vision as being affected, chiefly in the direction of not recognising what an object really was; and in this particular it reminded me of the dog Goltz speaks of in his experiments that was not frightened by objects that had caused him terror previous to being experimented on, because they had lost their significance to him. Further, both these cases illustrated the value of this disease as a method of investigation, as in each of them there was destroyed, without shock, hæmorrhage, or inflammation, a region that Ferrier tells us he thought it would be impossible to deal with, but the destruction of which was eventually accomplished by a very complicated method of operating.

I shall conclude my list of cases by detailing one in which I removed the cyst by operative measures, after allowing the animal to go through the various stages of the disease, and only interfering when the creature was moribund. I was anxious to satisfy myself as to the feasibility of removing the cyst, and as to whether its removal would restore functions that seemed in abeyance. With this view, I obtained a sheep in the earliest stage of the disease, when the only symptoms of the disorder evident were seen in its separating itself from the rest of the flock, and being more easily alarmed and excited. It was under observation for some weeks, and during that time the rotatory movement from right to left showed itself, together with loss of vision, first in the left eye and then in the right one, until, eventually it became like an animal deprived of its cerebral hemispheres. It stood in the field with its head pushed forward, quite listless, and refusing to eat. If it moved at all it was towards its right side, in a circular manner. It had become very emaciated, owing to its refusal to eat, and was dying of

starvation though in the midst of plenty. I felt that, if the creature was to be saved, the cyst must be removed, and, accordingly, in a surgical capacity, and not as a vivisector, I determined to extract the cyst. The rotatory movement being towards the right side, and there being a softened spot of bone about one inch posterior to the right horn, it was clear that the cyst occupied the right side of the brain. Previous to operating I ascertained that the sight of both eyes was gone, for holding a lighted candle in front of them and striking a match had no effect on the dilated pupils, and did not cause the animal to start. There was no paralysis of the limbs, although the legs on the left side of the body seemed weaker and more awkwardly placed. As I wished to introduce no disturbing element into the case, I did not administer any chloroform, and I performed the operation by Lister's method, taking every antiseptic precaution, for I knew that in this way I would diminish to a minimum the risk of inflammation, as I kept in mind the first case I had seen operated on, where putridity and its subsequent inflammation caused death. I will not give in detail all the steps of the operation, suffice it to say that I made a crucial incision over the soft portion of the skull, reflected the soft parts, cut through the softened skull and dura mater, and seized the cyst with artery forceps. By means of a fine trocar I evacuated its contents and pulled out the bag through the opening in the skull. An antiseptic dressing was applied, sufficient to last for some days, and I had the creature put under cover and artificially fed. The next day a most marked change was visible in the animal. It was no longer dull and lethargic, but paced rapidly about the place where it was confined, and fed on the hay placed for it. This improvement continued, interrupted only by some convulsive attacks which lasted for three or four days and then passed off. These I attributed to some accumulation of discharge in the interior of the cavity where the cyst had been, and from its position it was not easy to drain it. I anticipated some oozing into the cavity, but, under the antiseptic precautions used, I felt that it would not putrefy, and I trusted to its being absorbed, so I employed no drainage. At the end of a fortnight I was able to let the creature loose once

more in the park, where it was in no way to be distinguished from the other sheep. It grazed, moved about naturally, and was free from any rotatory movement. Before sending it out I tested its vision, and I found that in both eyes it was good, the hand drawn in front of either eye causing it to throw back its head, and the pupils responding to light. For six weeks after the operation I kept it alive, during which time it still further improved in condition, and it was impossible to tell that anything had been wrong with it. At the end of that period it was killed, and the head examined after death. On removing the calvarium there were some adhesions of the membranes to the skull at the spot where the cyst had been removed, and in the same locality the two sides of the hemispheres were joined by inflammatory matter, quite obliterating the median fissure. The cyst had evidently occupied the right upper posterior convolution, and had somewhat invaded the corresponding part of the opposite hemisphere. A point of interest showed itself when a section of the brain was made in the middle line. The inflammatory adhesions between the upper surface of the brain and the dura mater lining the skull had so pulled up the brain to the bony case that there had been formed in the interior of the brain a large single cavity, made up of the two lateral ventricles, owing to the corpus callosum being drawn up and the septum lucidum put on the stretch. Otherwise the brain was natural. Such is a brief outline of a case that, apart from its surgical result, had in it much that was interesting physiologically. The seat of the lesion approximated closely to Ferrier's centre for sight, but the complete return of that sense after operation indicated clearly that it was really only in abeyance. This case then shows, what Goltz's experiments also confirm, that many of the results obtained in experimental inquiries should be referred rather to disturbances of function than removal of function, and this possibility should always be borne in mind. I consider this case as very instructive in that respect. Had I not operated on it I should have regarded it as a case in which the visual centre had been destroyed by the cyst, whereas in reality the organ of sight was temporarily involved, owing to the disturbance set up in the mechanism of the brain by the presence of an irritant such as we have seen this

hydatid is. The return of a function that seemed destroyed, as soon as the source of irritation was removed, is only another instance of how careful we should be in drawing conclusions from experimental inquiries. I must not, however, dwell any longer on this point.

In concluding, I may say that I wish my observations had been more extended and been made with more thoroughness, but they were often conducted under considerable difficulties, and they were chiefly undertaken with the view of ascertaining whether the malady was one that would repay more extended observation. I think it would, and in the course of this paper I have noted several points which specially recommend it, so I need not recapitulate them here. In such a difficult study as that of the nervous system every source of information should be brought under contribution, no matter how small the harvest to be reaped. At present, owing to the discovery of Hitzig, the nervous system seems to be passing through a phase in its existence, of which there are many instances to be found in the history of physiology, where attention has been suddenly directed to some organ, which as a consequence is experimented upon in every way that the ingenuity of man can devise. Whether this is to be followed by a period of comparative neglect, time will only show; but if we look at mind and matter, there is nothing more remarkable than the reaction which characterises both. We see it in the pendulum which, obedient to the law of gravitation, returns to its centre, but, as it does so, swings to the other side. And so it is with a change of opinion in men; once aroused they are prone to pass from one extreme to the opposite, and allow themselves to be carried by the recoil beyond the middle line. In the history of the nervous system we seem to have reached a like period. The excitability of the brain is now in the ascendent, let us watch carefully that we are not carried by the reaction beyond the limits which facts warrant.

TWO CASES OF LESION OF THE TEMPORO-SPHENOIDAL LOBE OF THE BRAIN. By JAMES CARMICHAEL, M.D., F.R.C.P.E. With PATHOLOGICAL EXAMINATION. By D. J. HAMILTON, M.B., F.R.C.S.E. (Plate X.)

THE situation of the temporo-sphenoidal region of the brain is roughly indicated by its name, and corresponds in the skull externally to the locality of the temporal and part of the sphenoid bones. It consists of three convolutions,—the superior, middle, and inferior temporo-sphenoidal convolutions,—lying parallel with and below the great fissure of Sylvius.

In this part of the brain, according to Ferrier, we have in monkeys localised centres of special sensation, chiefly of hearing and smell. It has not been ascertained that lesions in this situation cause any motor paralysis.

The cases forming the subject of this paper are examples of circumscribed disease of this portion of the brain. The morbid anatomy of the one differs from that of the other, but the locality of the lesion being nearly identical, the two cases may not inappropriately be viewed together.

Before entering on their morbid anatomy, more particularly that of Case II., a consideration of which will form the principal part of the paper, it may be well to give a brief record of the symptoms observed in both. Case I. was that of a somewhat delicate lad of fifteen, who, five years before his death, received a blow on the head from a schoolmaster. This was followed by hæmorrhage from the right aural meatus, and subsequent otorrhœa, which continued up to the period of his death. His last illness continued six days. The symptoms observed during life were entirely of a negative nature as regards the abolition or disturbance of brain function. The lad's intelligence was unimpaired until shortly before his death. The leading symptom was intense headache referred to the vertex, and a certain degree of photophobia. There was no paralysis of sensation or motion, or any affection of cutaneous sensibility. Death took place suddenly. On *post mortem* examination the posterior three-fourths of the right temporo-sphenoidal lobe of the brain was

converted into a large diphtheritic-looking abscess, with grayish green sloughy walls. This portion of the brain was destroyed throughout its entire depth. Some small hæmorrhages were observed at the circumference of the abscess. After washing out the pus from the cavity, its walls looked like a gangrenous slough. The other parts of the brain were comparatively healthy. This case was diagnosed during life to be a cerebral abscess.

Case II., the leading symptoms of which I shall now relate, was not diagnosed as a case of organic cerebral disease at all. It was throughout an extremely obscure one, and although I had the benefit of the opinion of Professor Sanders, we could not arrive at any decided conclusion. On the whole, Professor Sanders agreed with me in thinking that the seizures to which the boy was subject might be of an epiliptiform nature, but even this was difficult to decide, because neither he nor I, unfortunately, ever had the opportunity of witnessing any of them. The boy was nine years of age, and was otherwise healthy. He was more than usually intelligent, and always occupied a high place in his class at school. The only symptoms which this boy presented were the seizures already referred to. These occurred at very irregular intervals up to the date of his death, sometimes several in a week, and often two or three weeks elapsing without their recurrence. From the description of the mother I give the symptoms. The attacks were of a very transitory nature, only lasting about a minute. They were generally characterised by a vacant and unnatural look, accompanied by slight incoherence of speech, the patient skulking into a corner of the room, as if afraid of something. After the attacks had passed off, the patient said he did not feel anything the matter. As the seizures were not characterised by exactly the same symptoms on all occasions, I mention two which were peculiar. One morning, while the nurse was dressing him, and his hair was being brushed, he suddenly sank down in a crouching manner on the floor, and crawled underneath the bed,—his parents believed, to get into the dark, for he seemed to avoid the light. On another occasion he was walking with his father in a level street in the New Town, when he suddenly remarked that the street was too steep, became confused for a few seconds, and then regained his natural manner. During

most of the seizures it was noticed that he put up his hand to his forehead or over his eyes, as if he wished to exclude light, or felt pain in the head. Such are the leading facts of the case. In other respects the boy enjoyed excellent health, and was active and intelligent. All the organs, including the kidneys, yielded, upon examination, negative results as regards disease. There was no paralysis, anæsthesia, hyperæsthesia, or any other nervous symptom, although these were anxiously and repeatedly looked for. The special senses were apparently intact. I regret having omitted to examine the eyes ophthalmoscopically. Had this been done, and any degree of optic neuritis or other retinal lesion discovered, it might have given a key to the case, which was otherwise very obscure, and the diagnosis of which, up to the time of the patient's death, was quite undecided.

The boy's illness from the first onset of these symptoms lasted about four months. Death occurred somewhat suddenly. After passing a restless night, he had a rigor, which was succeeded by a rise of temperature to 101·8. He became somnolent about an hour before death, which took place twelve hours after the supervention of the rigor. The *post mortem* examination was made twenty hours after death by Mr Hamilton. Professor Sanders was also present. The body was well nourished, and presented no abnormal appearance externally. The head alone was examined. The calvaria on removal presented unusually well-marked impressiones digitatæ, in the concavities of which the bone, by transmitted light, appeared thinner than natural. On reflecting the membranes, no unnatural appearance was observed. The brain was then removed *en masse* for further examination. The only abnormality which now appeared was situated in the left temporo-sphenoidal lobe, which presented the following characters.

It appeared more prominent than usual, especially towards its lower part, in the situation of the middle temporal convolution, and was slightly paler than the surrounding brain substance. On grasping it in the hand it felt of harder consistence than normally, in some places almost like that of cartilage. There was no distinct projecting and isolated tumour, but the borders of the indurated mass insensibly passed into the surrounding healthy brain tissue. The appearances were more like those of an infiltration of some new material into the brain substance,

spreading diffusely throughout it, without destroying the outline of the convolutions. It would have been called a "sclerosis" by certain pathologists, but as this term is used so indiscriminately I have purposely avoided it.

The whole temporo-sphenoidal lobe seemed to be more or less involved, but the middle third of the second temporal convolution was the chief seat of the lesion. On cutting horizontally through it, no line of demarcation of the grey from the white substance could be noticed, apparently from the absence of the former. This was most evident at the point where the induration was best developed.

The consistence of the indurated part was tough and somewhat gelatinous, while in certain places it reminded one of hyaline cartilage. It did not, however, appear to be myxomatous. The induration was most marked in the grey matter, but extended for about half an inch to an inch into the white. The edges of the section were clean cut, and, unlike brain substance, retained their sharpness, even after having been somewhat roughly handled in manipulating the brain. The boundaries of the tumour could be much better felt than seen, the absence of induration indicating where the natural brain tissue commenced.

The colour of the tumour was greyish-pink, with an almost pearl-like lustre at the edges.

The parts were hardened in the method recommended by me (this *Journal*, vol. xii.), in which potassium and ammonium bichromates are the chief media. They were afterwards cut in the freezing microtome. Some of the sections were stained in picro-carmine and mounted in Farrant's solution; and, examined in this way with a magnifying power of 300 diams., the whole cortex was seen to be infiltrated with what looked like small, round, or somewhat irregularly shaped, sarcomatous cells (fig. 2). These had large nuclei, and some of them possessed several, and seemed to be actively proliferating. Occasionally, when a cell became isolated, as at the margin of the section, one or two delicate processes might be seen radiating from the cell body. The intermediate substance in which these cells were implanted looked as if composed of finely granular matter having an amorphous character. A nerve cell or fibre could sometimes be seen, but they were comparatively rare, the greater number of them

having apparently undergone atrophy from the pressure of the cellular growth between them. Blood-vessels were abundant, and in no part had any fatty degeneration as yet occurred. Every feature showed the tumour to be actively growing and in an embryonic condition.

Such a description corresponds with that originally given by Virchow (*Die krankhaften Geschwülste*), of what he called gliomatous or neuro-gliomatous tumours, a class of new formations which he tabulated as being closely related to the round cell sarcomata. In later times they have been universally included under the class sarcomata, irrespective of their origin from the brain, spinal cord, or retina. They are now usually described as round cell sarcomata, and when examined by the ordinary methods, their histological features certainly warrant such a designation. We shall, however, see that this tumour, which I have described as like a round cell sarcoma, proved to have a totally different structure when examined with other methods of preparation. We have stated that the first sections taken from the tumour were mounted in Farrant's solution, a fluid having much the same properties as glycerine, and that the structure brought out by this means was that of a round cell sarcoma. Some others were stained in carmine, and were then *entirely clarified* in oil of cloves and mounted in solution of gum damar, but still presented the structure of a round cell sarcoma, with an amorphous basis substance.

Another method was, however, adopted, which revealed appearances previously unsuspected. It consisted in rendering the section half transparent in oil of cloves, and then preserving it while in this state in solution of gum damar. The method is excellent for bringing into view the structure of a dense tissue such as the cerebral cortex.

When examined in this way as great a change was noticed in the histological appearances as in a cornea, before and after staining with silver or gold. The cells, which formerly appeared like those of a round-cell sarcoma, were now observed to be most extensively branched, constituting a close-meshed network by the intertwining and anastomosis of their processes. From some cells as many as thirty to forty processes were seen to come off, which, after running for a short distance, either ended

in free extremities or joined with those from other cells. When a very thin piece of the tumour was examined with a magnifying power of 450 diams., the true structure of the intermediate apparently granular substance became apparent. It was entirely composed of the processes which radiated from the edges of the cells, and the granular appearance previously referred to was found to be due to these seen in optical section. I could not detect any granular matter in places where the section was thin enough to show a single layer of cell elements, and believe that it was merely an optical effect of the density of the plexus of cell processes.

The cells of the tumour were now seen to have an entirely different character from that formerly observed. They proved to be delicate protoplasmic masses (fig. 1), varying in shape, the commonest being like the "Spinne Zell" of German authors. In such cases what would correspond to the sphæro-gastric body of the animal, generally represented a large nucleus (fig. 1, *b.*) separating from the parent cell. Others, however, were round or flattened, with long peninsula-like offshoots running from them, and in their transformations much resembled the protean forms of an amœba. The nuclei subsequently became detached (fig. 1, *c.*), and for some time remained as round or oval cells, but subsequently developed processes like the parent cell from which they originated. Within most of the cells beautiful intranuclear and intracellular protoplasmic plexuses, as described by Heitzmann, Fleming, and Klein, could be detected, and it seemed as if the multiform transformations in the shape of the cells were produced by their contraction. The intracellular plexus frequently extended for some distance into the cell processes. The whole cell body, nuclei, and processes seemed to have an eminently protoplasmic character, no part as yet having become converted into a "formed" material.

Capillary vessels ran abundantly throughout the tumour, and the cell processes formed a dense plexus around them. As by the former methods of preparation, so by this, fatty or other degenerative changes were not noticed in any part.

The cells of this tumour closely resembled the connective tissue corpuscles naturally found in the supporting connective tissue of the nerve centres. They were figured several years

ago by Rindfleisch (*Lehrbuch der pathologischen Gewebelehre*), as occurring in the spinal cord in locomotor ataxia, and have been more recently shown by Krause (*Handbuch der Menschlichen Anatomie*) to be present in the connective fibrous tissue of the normal brain and spinal cord. In the spinal cord they lie between the nerve-tubes, and constitute part of their wall. Previous to the examination of this tumour I had occasionally seen them in the normal brain, every here and there, in sections of the cortex, but never in anything like the abundance noticed in this tumour.

There seems little doubt that the cells just described were directly derived from these by a process of nuclear proliferation, and that the tumour in all respects was of a connective tissue type, and corresponded with the gliomatous sarcoma originally described by Virchow (*loc. cit.*). The structure revealed by this method of preparation is however different, so far as we are aware, from anything that has ever been fully demonstrated in such tumours, and seems to throw some light upon the probable structure of the normal neuroglia.

Such is the description of the morbid anatomy of the brain in this case, which I think it will be admitted is of considerable interest. Before concluding, it may be asked, what is the value of such cases from a clinical point of view, and in relation to the functions of this portion of the brain as at present believed in by physiologists? The latency of organic cerebral disease, even where large portions of brain substance are involved, is one of the best ascertained facts in human pathology, and at the same time one which involves some of the most puzzling and mysterious problems which physicians and physiologists are jointly called upon to solve. Thanks to the laborious investigations of Goltz and Hitzig, Charcot and Pitres, Ferrier, and others, as carried on by the joint methods of physiological experiment and clinical and pathological observation—methods which must go hand in hand if science in this department is to advance—much light is being thrown upon the functions of various parts of the brain. Already the battle is going on between localisation and generalisation in brain function. At present those observers who believe in localisation are not by any means at one in their opinions. Thus, Ferrier's views are assailed on many

points by Brown Sequard, and by Munck, and it is evident that we must patiently wait yet longer before arriving at definite conclusions. The portions of the brain destroyed in the cases narrated are credited with being the great centres of special sensation, more especially of hearing, yet by ordinary tests these functions were quite unimpaired. To account for absence of loss of special sense in such cases as these, we must either abandon the idea of localisation in brain disease, or explain the clinical facts by the bilateral representation of function in the hemispheres. Ferrier admits the probable partial correctness of this latter hypothesis in explaining cases of a slowly progressive character, and says, "but that there is no impairment at all of sensory perception or discrimination in sudden unilateral lesions, or even in chronic lesions, is a fact which I do not admit as proved; and I adopt the alternative supposition, that the latency has been in the observation rather than in symptoms,"—a poor compliment to the ordinary unaided senses of the clinical physician. Again, Ferrier admits generally that many facts which he himself has noted in his Gulstonian lectures, show, to use his own words, an "apparently irreconcilable discrepancy between human pathology and experimental physiology," so that we are only yet on the threshold, as regards definite results, of these inquiries. No department of medical science, however, has a more able band of workers than this, and it cannot be doubted that ere long many dark problems will be worked out, and hitherto irreconcilable facts explained.

I therefore record these two examples of localised cerebral lesion as an addition to the already large number of similar ones which have been published of late years, in the hope that their further accumulation may assist those who are striving to work out many obscure points in the physiology and pathology of the brain.

EXPLANATION OF PLATE X.

Fig. 1. Section of the tumour half clarified in oil of cloves and gum damar (× 450 diam.):—*a*, a capillary blood-vessel; *b*, one of the cells proliferating; *c*, a separated nucleus.

Fig. 2. Appearance of same section examined in Farrant's Solution. The branched condition of the cells not visible, and the intermediate substance finely granular (× 300 diam.).

TWO CASES OF STRIATED MYO-SARCOMA OF THE KIDNEY.

By WILLIAM OSLER, M.D., M.R.C.P.L., *Professor of the Institutes of Medicine, M'Gill University, Montreal.*

TUMOURS containing striped muscle fibres (*Myoma strio-cellulare* of Virchow; *Rhabdomyoma* of Zenker) are oncological curiosities. Between twenty and thirty cases are on record, the majority of which have been found in connection with the testicles or ovaries. Eberth[1] first described a tumour of this nature in the kidney in 1872, Cohnheim[2] a second in 1876, since which date four other cases have been recorded by Marchand,[3] Landsberger,[4] Kocher and Langhans,[5] and Huber.[6]

All the cases occurred in children from 7 to 39 months old. The tumours were large, the weights ranging from 587 to 5500 grammes. In one instance both organs were affected. In two there were secondary masses in the liver, in one of which muscle fibres were found. All of the tumours correspond very closely in histological characters, being composed of a sarcomatous basis of round cells, traversed by bands of firmer, fleshy tissue, in which the muscle fibres occurred.

The following cases have come under my observation in the past two years:—

CASE I.—*Striated Myo-Sarcoma of left kidney. Death with gastro-intestinal symptoms.*

George H., aged 19 months, patient of Dr Dugdale. Had been a healthy child. On March 23d, 1878, he was vaccinated in the morning, after which he appeared in his usual health. At two o'clock P.M., he began to vomit and have severe gastro-intestinal symptoms. They yielded to treatment, but the child sank and died at two o'clock the same evening. At the autopsy on the following day nothing unusual was found except a tumour

[1] *Virchow's Archiv*, Bd. lv.
[2] *Ibid*, Bd. lxv.
[3] *Ibid*, Bd. lxxiii.
[4] *Berliner Klin. Wochenschrift*, 1877.
[5] *Deutsche Zeitschr. f. Chir.* Bd. ix.
[6] Huber, *Deutsches Archiv. f. Klin Medecin*, Bd. xxiii. 1878.

of the left kidney, which was removed and sent to me for examination.

Organ is enlarged and has the shape of a blunt pyramid, the convex border projecting, the inner surface, with the hilus, presenting a tolerably straight line, extreme length over outer border, from one end to the other, 16 centimetres. The capsule is thin, detaches easily, and a large white mass can be seen through the thin layer of cortex on the convex border. On section, the central part of the organ is occupied by a tumour measuring about 7 centimetres in each direction, broadest at the pelvis with which it is in contact, and gradually narrowing towards the outer border, where it is separated from the capsule by a layer of kidney substance 2 to 3 m. in thickness. At the upper and lower ends of the organ the cortex and cones are still to be seen though somewhat diminished in volume. In its growth the tumour has expanded the renal substance in such a way that a progressively diminishing layer covers it from the ends towards the centre. The mass is not encapsulated, but at the margins can be seen penetrating the kidney tissue, strands of which separate the advancing portions. The cut surface of the tumour is greyish-white, and has a porous spongy appearance, from the presence of small irregular spaces. Bands of translucent-looking tissue pass in all directions, crossing each other and dividing the substance into areas which are occupied by a soft granular substance. Some of the strands passing from the deeper parts are 2 m. in thickness. The pelvis and calyces are somewhat compressed; the ureter opens directly below the centre of the mass, artery and vein normal.

CASE II.—*Striated Myo-Sarcoma of left kidney. Sudden death from blocking of pulmonary artery and tricuspid orifice with sarcomatous thrombi dislodged from renal vein.*

C. S., female child, aged 3¼ years, patient of Dr Finnie's. Had been ailing for about six weeks with gastric and intestinal symptoms, occasional vomiting, and obstinate constipation. Slight pain in abdomen, and on inspection a tumour was discovered in left hypochondriac region, just below the cartilage of the 8th rib. It was soft and apparently fluctuated. Child had not been confined to bed. On getting up one morning and

walking towards her mother's bed, she was suddenly seized with a "choking fit," and died in a few moments.

Autopsy.—Body well nourished. On opening abdomen a tumour is seen on the left side, covered by peritoneum and descending colon and occupying the position of the left kidney. Spleen is pushed up, and the end of the tumour projects beneath the costal border in the axillary line; this superficial portion is quite soft, and apparently fluctuates. Tumour had no attachments, and peeled out readily; numerous veins course over it in front. It is ovoid in shape, large and rounded below, pointed above where it is capped by the adrenal. Anterior and upper surfaces dark and hæmorrhagic-looking; on the under surface there is natural-looking kidney substance for 2–3 centimetres about the hilus. *Renal artery* natural. *Renal vein* of large size, and when slit open, soft pulpy matter is seen oozing from the organ into it. The wall is rough, irregular, and covered with bits of soft greyish tissue. *Ureter* is pervious, not dilated; pelvis small; calyces at each end compressed. On section through the long axis of the tumour it presents the appearance of a soft rapidly-growing neoplasm. Above and in front, the tissue just within the capsule is deeply infiltrated with blood, and in places occupied by clots; the greater part of the exposed surface is made up of greyish-white, soft, cerebriform material. At the upper part two pyramids of kidney substance are surrounded by the new growth; the remnants of the organ at the under and lower surfaces are not seen on this section. Tumour measures 15 centimetres in length by 7·5 in breadth, and is about the size of a cocoa-nut.

Heart of normal size; right auricle contains much blood. Lodged in the auriculo-ventricular orifice is a firm greyish-white mass, 25 m. long 12 m. broad, not adherent, and without any fibrinous flakes upon it. Right ventricle contains dark clotted blood; in orifice of pulmonary artery there is another firm greyish-white mass about the size of a hazel nut, and beyond it in the right branch are two or three smaller bits of the same character.

Lungs somewhat congested at bases; no secondary masses.

Histological examination.—Case I. Tumour is made up of a soft greyish-white substance enclosed in irregular spaces formed

by bands of firmer tissue which pass in various directions through the mass. The former is composed of round cells about the size of colourless blood corpuscles; protoplasm finely granular, and with a single large nucleus. Some of the cells are a little irregular in outline, and in teased bits from the peripheral portions renal epithelium is occasionally seen. A scraping from the tumour or bits picked out from the interspaces consist entirely of the round cells, and the same are seen in sections closely packed together without any apparent intercellular substance.

The strands of firmer tissue consist of (1.) elongated spindle cells, the majority of which have prolonged extremities; others are flatter without the long processes and bear a strong resemblance to unstriped muscle fibres. They are either closely arranged together or are separated by a delicate wavy fibrillar tissue, which in places makes up the chief part of the bands. The cells possess a single elongated nucleus. They are from 0·0625—0·1 m. in length. (2.) Striped muscle fibres, occurring in variable numbers among the spindle cells and fibrous tissue of the septa, usually in bundles of 20 to 40; more rarely isolated fibres are met with. They do not often cross each other but keep parallel. When isolated they form flattened band-like fibres, ranging from 0·0625—0·375 m. in length, and from 0·0075—0·01 m. in breadth. The majority of them are not more than 0·0075 m. broad, while some of the less perfect fibres are narrower, 0·003—0·004 m. Most of the fibres have the same diameter throughout, others are larger at the centre and taper towards the ends, which are either square-cut or obtuse, less frequently pointed. The prominent feature is the distinct transverse striation, the substance of each fibre presenting cross lines, which are seen to be due to alternate light and dark areas in the tissue, the latter being the broadest. In large well formed fibres the striation is as distinct as in ordinary muscle; indeed, I have rarely seen in any specimen the "sarcous elements" so well marked. The majority of the fibres are nucleated; in some long ones three or four nuclei are arranged one after the other, and are connected together by a granular protoplasm. Scarcely any of the cells are striated in all parts; the nucleus and a central extension remain free, and the stria-

tion is confined to the outer borders. In wide fibres a longitudinal striation can be seen, but a separation into distinct fibrillæ was not met with. The nucleus is central, usually oval in shape, and a nucleolus is sometimes visible. So far as could be ascertained the fibres do not possess sarcolemma. Many cells were partially striated; sometimes a long band-like fibre had two nuclei; one end was distinctly striped, the other had the appearance of a smooth muscle fibre. Sometimes a fibre cell was seen with a small part of the protoplasm striated. A peculiar form of cell was club-shaped with a large nucleus and very plain striæ; others of the same shape were not striated, or had very faint transverse bars near the nucleus. In some places groups of flattened non-striated fibres were met with, which resembled closely involuntary muscle fibres. These appear to be intermediate forms between the fusiform cells, the smooth band-like fibres, and the fully-developed striated ones.

Case II. Tumour is made up of soft greyish substance, which consists chiefly of round cells a little larger than colourless blood corpuscles, and with single large nuclei. They are closely packed together with very little intervening tissue, and do not present an alveolar arrangement. Bundles of fusiform cells and connective tissue fibres pass through the structure in various directions, but do not form such definite bands as in the previous specimen. The fibre cells are elongated and have large oval nuclei. Some form flattened bands like smooth muscle fibres. Scattered among these elements in variable numbers are striated muscle fibres resembling those described in Case I. They are not, however, nearly so abundant, but in almost every specimen taken some examples were met with. In the mass which had lodged in the right auriculo-ventricular orifice they were very plentiful. They present similar characters to those above described; flattened, nucleated cells, with transverse striation. In some the striæ are scarcely visible, in others only part of the protoplasm is striated. In this specimen the fibres did not form such large bundles, nor were they so long.

THE SEQUENCE AND DURATION OF THE CARDIAC MOVEMENTS. By GEORGE A. GIBSON, M.B., D.Sc. Edin. (PLATE XI.)

FURTHER observations on the case of presternal fissure, described by Dr Malet and myself in the last number of this *Journal*, have entirely confirmed the views then expressed, and have at the same time brought some interesting facts to light.

The proximity of the base of the heart to the surface, allowing, as it does, such a careful comparison of sounds and movements through the fissure, affords a favourable opportunity for analysing the sequence and measuring the duration of events in the cardiac cycle. By means of a direct cardiograph, a low-pitched tuning-fork, and a rapidly revolving cylinder, tracings resembling those already published in every respect have been obtained. In this paper a study of these tracings is proposed.

Unfortunately the only method of combining rapid revolutions of the cylinder with the registration of tuning-fork vibrations is the use of smoked paper, so that a continuous tracing of greater length than the circumference of the cylinder cannot be taken. In the two tracings figured on Plate XI. the vibrations of the tuning-fork, of which each complete excursion occupies the one-hundredth of a second (·01 sec.), are recorded below the waves traced by the lever of the cardiograph. The impulse caused by auricular systole is taken as the starting-point, through which is drawn an arc of a circle parallel to and with the same radius as the arc described by the lever of the cardiograph before the commencement of cylinder rotation. Similar parallel arcs are drawn through the successive impulse waves, and each, at its intersection with the tuning-fork curve, marks off the fraction of a second occupied by the corresponding cardiac phase.

Before taking up the tracings, a brief retrospect may be cast over the work of previous observers. Passing over that of Volkmann[1] as unreliable, the earliest trustworthy measurements of the cardiac

[1] *Zeitschrift für rationelle Medicin*, 1842, s. 321, quoted by Donders.

movements are those of Donders,[1] who accompanied the sounds of the heart by movements which were registered along with electric signals from a clock. In this way he found that the interval between the first and second sounds, which he took to represent the ventricular systole, varied between the limits of ·309 and ·327 sec., and was tolerably constant for the same individual with a high as well as with a low pulse-rate. In the sitting posture the systole, as compared with the whole cycle, was relatively shorter although absolutely longer. From such considerations Donders concluded that the systole has an independence of its own. By means of a Marey's sphygmograph Landois[2] carefully measured the different movements of the heart at the apex-beat. To afford the means of easy comparison with the figures in the sequence, the following table is taken from his paper:—

a. Dauer der Vorhofcontraction bis zum Beginn der Ventrikelsystole, ...	0,170	0,177
b. Dauer der Ventrikelcontraction, ...	0,155	0,192
c. Verharren des Ventrikels in der Contraction, . .	0,088	0,082
d. Vom Beginn der Diastole bis zum Schluss der Semilunarklappen, ...	0,066	0,072
e. Dauer der Diastole vom Schluss der Semilunarklappen bis zum Beginn der Pause, ...	0,259	0,200
f. Dauer der Herzpause, ...	0,393	0,407
Dauer des gauzen Herzschlages, ...	1,133	1,133

In this table *b*, *c*, and *d* represent the systole as measured by Donders.

And now, turning to the Plate appended to this paper it will be observed that the four auricular contractions, beginning with *a*, extend in fig. 1 over 10½, 10½, 10, and 11½ vibrations of the tuning-fork respectively, or occupy ·105, ·105, ·100, and ·115 sec. each; the same act taking up in fig. 2, ·115, ·110, ·110, ·110, and ·110 sec. during each cardiac revolution. The duration of the next stage, beginning with b^1, and representing the initial shock of ventricular contraction, is in fig. 1, ·055, ·060, ·055, and ·060 sec.; and in fig. 2, ·065, ·060, ·060, ·060, and ·060 sec.

[1] *Nederlandsch Archiev voor Genees-en Natuur-kunde*, 1865, b. 139, and *Dublin Quarterly Journal*, 1868, p. 225.

[2] *Centralblatt der medicinischen Wissenschaften*, 1866, s. 179, and *Zeitschrift für rationelle Medicin*, 1867, s. 413.

for each cycle. Following this, the fall of the lever from b^2 during the expulsion of the blood from the ventricles occupies in fig. 1, ·180, ·225, ·205, and ·200 sec., and in fig. 2, ·175, ·180, ·175, and ·180 sec. From the cessation of the descent at b^3 to the shock accompanying the second sound are intervals in fig. 1 of ·155, ·105, ·120, and ·130 sec., and in fig. 2 of ·150, ·135, ·130, and ·140 sec., and from this latter point c^1, which may be taken to represent the commencement of diastole as determined by the ear, until the ascent of the lever caused by the influx of blood during ventricular relaxation are pauses in fig. 1 of ·080, ·115, ·100, and ·100 sec., and in fig. 2 of ·105, ·110, ·110, and ·105 sec. The diastolic filling of the ventricles, beginning with c^2, takes up in fig. 1, ·140, ·105, ·105, and ·110 sec., and in fig. 2, ·120, ·115, ·100, and ·120 sec., after which the revolutions end in long pauses, lasting in fig. 1, ·385, ·470, and ·395 sec., and in fig. 2, ·330, ·330, ·260, and ·240 sec., during each of which the slight rise of the curve shows a gradual increase of tension caused by the continued ingress of blood.

To present the foregoing measurements in a more useful form, they are embodied in the following tables, of which the first belongs to fig. 1 and the second to fig. 2:—

	I.		II.		III.		IV.		
Auricular contraction,		·105		·105		·100		·115	Auricular systole.
Ventricular shock,	·055		·060		·055		·060		
Expulsion of blood,	·180	·390	·225	·390	·205	·380	·200	·390	Ventricular systole.
Pause to arterial recoil,	·155		;105		·120		·130		
First diastolic pause,	·080		·115		·100		·100		
Return of blood,	·140	·605	·105	·690	·105	·600	·110	·625	Diastole.
Second or long pause,	·385		·470		·395		(·415)		
Entire cycle,		1·100 sec.		1·185 sec.		1·080 sec.		1·140 sec.	

	I.		II.		III.		IV.		
Auricular contraction,		·115		·110		·110		·110	Auricular systole.
Ventricular shock,	·065		·060		·060		·060		
Expulsion of blood,	·175	·390	·180	·375	·175	·365	·180	·380	Ventricular systole.
Pause to arterial recoil,	·150		·135		·130		·140		
First diastolic pause,	·105		·110		·110		·105		
Return of blood,	·120	·555	·115	·555	·100	·470	·120	·465	Diastole.
Second or long pause,	·330		·330		·260		·240		
Entire cycle,		1·060 sec.		1·040 sec.		·945 sec.		·955 sec.	

In the next table are embodied the measurements of at least one complete revolution of every cardiogram now in my posses-

sion, taken on the basis of the second sound being the point of separation between systole and diastole.

No. of Tracing and of Cycle.	Auricular Systole.	Ventricular Systole.	Diastole.	Entire Cycle.	No. of Tracing and of Cycle.	Auricular Systole.	Ventricular Systole.	Diastole.	Entire Cycle.
1. I.	·115	·345	·605	1·065	10. II.	·105	·390	·690	1·185
2. I.	·120	·350	·670	1·140	11. I.	·105	·365	·465	·935
3. I.	·125	·355	·670	1·155	II.	·100	·380	·495	·975
4. I.	·130	·375	·660	1·165	III.	·100	·355	·485	·940
5. I.	·125	·335	·455	·915	12. I.	·130	·385	·625	1·140
II.	·125	·345	·455	·925	II.	·105	·375	·615	1·095
6. I.	·125	·360	·490	·975	III.	·105	·355	·575	1·035
II.	·125	·355	·575	1·055	13. I.	·115	·390	·555	1·060
7. I.	·115	·375	·570	1·060	II.	·110	·375	·555	1·040
II.	·110	·360	·525	·995	III.	·110	·365	·470	·945
8. I.	·105	·375	·565	1·045	IV.	·110	·380	·465	·955
II.	·110	·380	·560	1·050	14. I.	·105	·390	·605	1·100
9. I.	·105	·335	·675	1·115	II.	·105	·390	·690	1·185
II.	·105	·325	·675	1·105	III.	·100	·380	·600	1·080
10. I.	·110	·395	·685	1·190	IV.	·115	·390	·625	1·140

The average absolute duration of each phase with that of the entire cycle is—

Auricular Systole.	Ventricular Systole.	Diastole.	Entire Cycle.
·112 sec.	·368 sec.	·578 sec.	1·057 sec.

The limits of absolute duration of each phase, as well as the difference, may be stated as follows :—

	Longest.		Shortest.		Difference.
Auricular Systole, . . .	·130	—	·100	=	·030 sec.
Ventricular Systole, . . .	·395	—	·325	=	·070 sec.
Diastole, ...	·690	—	·455	=	·235 sec.

And the difference as compared with the shortest absolute duration expressed in percentage gives the following table :—

Auricular Systole, . .	·030	:	·100	=	30 per cent.
Ventricular Systole, . .	·070	:	·325	=	21·3 ,,
Diastole, ...	·335	:	·455	=	51·6 ,,

which clearly shows the extent to which the duration of each phase may vary from its lowest limit.

Leaving the absolute duration of the individual parts of the cardiac cycle, the variations in the relative duration of each, as

compared with the entire revolution to which it belongs, may be arranged in the following percentages:—

		Shortest.			Longest.	
Auricular Systole	in 14. II. is	8·8 per cent.	and in	5. I. is	13·7 per cent.
Ventricular Systole	,, 9. II. ,,	29·4 ,,	,,	13. IV. ,,	40·6 ,,
Diastole,	,, 5. II. ,,	49·1 ,,	,,	9. II. ,,	61·1 ,,

All these tables show clearly that the most stable part of the cardiac revolution is the ventricular systole. The duration of the diastole, upon which the rate of the heart-beat mainly depends, is the most variable, and next to it must be ranked the contraction of the auricles.

Compared with the measurements of Donders the interval between the first and second sounds is somewhat longer. The percentage on the entire cycle according to him is rather higher, being from 40·6–45·6 as against 29·4–40·6; and the instance of slow pulse which he gives[1] increases the range to from 18 to 45·6 per cent. According to Landois the constancy in duration of the auricular systole and of the diastole is to be noted, while the variations in ventricular contraction approach those in the foregoing tables rather closely.

Before concluding there is one point to be briefly adverted to. In fig. 2 there is a wave between b^3 and c^1 which is marked c^4. The two successive impulses c^4 and c^1 have a cause not far to seek, for they can only arise from a difference in time between the arterial recoil towards the two sets of semilunar valves. In the same tracing there is a shoulder, marked b^4, on the descending ventricular curve, which occurs in about half the total number of tracings, being invariably associated with the impulse c^4. These two waves therefore are evidently interdependent. Arcs of the lever circle are drawn through these points in the manner already described, and from them the interesting fact is learned that the number of vibrations occurring between b^4 and c^4 is in each cycle exactly that already found between b^3 and c^1. The interval of time between b^3 and c^1 is ·150, ·135, ·130, and ·140 sec. in each cycle, and between b^4 and c^4 the length of time which has elapsed is the same. The conclusion is obvious, that b^3 marks cessation of ventricular contraction and c^1 arterial

[1] *Loc. cit.*

recoil, and that in like manner b^4 is the point also of cessation of ventricular contraction, followed at the same interval by c^4 arterial recoil.

Discussion of the cause and mode of occurrence of this separation of the arterial recoil in the aorta and pulmonary artery is, in this paper, beyond the mark. Passing over the attempt of von Bamberger[1] to explain reduplication of the aortic second sound by an irregular contraction of the arterial walls, causing successive blood-waves towards the sigmoid valves, as based upon the erroneous conception that the arterial systole is of muscular instead of elastic origin, the first theory founded on rational principles was that of Potain,[2] who gave difference of pressure within the aorta and pulmonary artery as the cause. No criticism of this will be undertaken now, but in a future paper the subject will be discussed.

A difficulty besets the double arterial recoil of the tracing, inasmuch as there never has been an audible reduplication, although the second sound has always been extremely loud and prolonged. This might be explained away by saying, that like physiological reduplication in general, it is evanescent and only present occasionally. But the reduplication is more persistent than that frequently present at the end of inspiration and beginning of expiration, for it takes place during the whole length of many tracings which were obtained under ordinary conditions of respiration; indeed, it seems much more probable that the reduplication of the recoil may be present without reduplication of the sound being audible.

According to Despretz, quoted by Carpenter,[3] the minimum number of complete vibrations required to produce an appreciable musical sound is eight per second, and Savart, also quoted by Carpenter,[4] fixes the minimum at from seven to eight per second. Contradictory statements are made with regard to the duration of sonorous impressions on the ear, this being said by some observers to be longer and by others shorter than the duration of ocular impressions. Foster[5] says that "the ticks of a

[1] *Lehrbuch der Krankheiten des Herzens*, 1857, s. 73.

[2] *L'Union Médicale*, N. S. tome xxxi. 1866, pp. 307, 357, 438, 595, 611.

[3] *Principles of Human Physiology*, edited by Power, 1876, p. 836.

[4] *Loc. cit.*

[5] *A Text-Book of Physiology*, 1878, p. 456.

pendulum beating 100 in a second are readily audible as distinct sounds." In the reduplication on the tracing the arterial recoils are separated by the tenth part of a second; yet it must be borne in mind that the sound accompanying each is not a simple noise, but, caused as it is by the vibrations of a membrane and a column of fluid with the secondary vibrations of the surrounding structures, approaches the character of a musical note. It seems much more probable that the one sound is continued into the other than that the reduplication should play at hide-and-seek with the observer.

Explanation of Plate XI.

The figures along the tuning-fork curves indicate the number of vibrations in each period, and the tracings are to be read from *left* to *right.*

ON THE FŒTAL MEMBRANES OF THE ELAND (*OREAS CANNA*). By Prof. TURNER, M.B., F.R.S.

IN the month of June 1879 I received from my friend the late Professor A. H. Garrod,[1] the fœtal membranes of an Eland, which had given birth to a young one in the Gardens of the Zoological Society of London.

When spread out on a table the chorion was nearly 7 feet in length, and obviously consisted of two horns, one of which, much more dilated than the other, had contained the fœtus. This dilated horn was torn at and near the spot which had been in relation to the os uteri. The amnion was so torn that its relations and connections could not be accurately followed out. The tubular prolongations of the allantois could be traced into each corner close up to its tip, but owing to the injury it had received during parturition, nothing definite can be stated of the arrangements of this sac within the part of the chorion where the fœtus had been lodged.

The outer surface of the chorion was studded with upwards of 100 caruncules, which varied in diameter from $\frac{1}{4}$ inch to 4 inches, but the majority were from 2 to 3 inches across. They were sessile on the chorion, and as a rule limited by a well-defined edge, but with those situated near the free end of each horn the chorion was puckered in around the base of attachment, so as to simulate a somewhat peduncular arrangement.

The caruncules were closely crowded with villi, which were elongated, and in the centre of the caruncule measured from $\frac{3}{10}$ths to $\frac{4}{10}$ths inch in length. The stem of origin of each villus was short, for it almost immediately bifurcated into two slender cylindriform branches, and these again branched repeatedly in a dichotomous manner, until at last they terminated in a bunch

[1] I cannot allow this opportunity to pass by without expressing my indebtedness, not only on this, but on previous occasions, to the late Professor Garrod, for specimens of rare forms of placentæ. I always found him ready to assist in procuring the material for research, and in the most unselfish way placing it at my disposal. In common with so many fellow-workers in anatomy, I regret the loss that science has sustained by the early death of one who stood in high estimation, not only from his ability and attainments, but from the excellence of his personal character.

of very slender thread-like villi. No collateral branches arose except close to the origin of the parent stem of each villus, where it was not unusual to see one or two short leaf-like villi projecting from the parent stem. Long vessels, which could readily be injected, passed down the axis of the cylindriform villi, and gave orgin to a network of capillaries distributed near the surface of the villus. The plexus was very distinct in the leaf-like villi above referred to, as these vessels arose from the vessels of the villi, where they were comparatively large in size, whilst the capillaries in the cylindriform branches were more difficult to fill with injection, on account of the length and fineness of the vessels from which they proceeded.

The intercotyledonary parts of the chorion were as highly vascular as I have seen and described to be the case in various other specimens of the cotyledonary placenta. The last caruncule was situated in the more distended horn 3 inches from its tip, but in the less distended 5 inches. As a good injection of the vessels had been obtained in the latter, the chorion beyond the terminal caruncule was minutely injected up to its free end, except in two or three patches where the injection had failed to penetrate the vessels. One uninjected patch was circular in form and ¼ inch diameter; it was surrounded by a highly vascular portion of the chorion, and was, I believe, a non-vascular area in relation to the orifice of the Fallopian tube, similar to what I have described in the placenta of *Orca*, the mare, and other mammals.

No appendage was situated at the tip of either horn of the chorion, which could be regarded as a *diverticulum allantoidis;* so that the Eland differs in this particular from the cow and sheep, and resembles what I have seen and described in various of the Cervidæ. The intercaruncular surface of the chorion was not mapped out into minute polygonal areas, such as I have previously described in the cow, giraffe, and raindeer.

Patches of a very delicate brownish filmy membrane existed on some parts of the intercotyledonary chorion. This membrane could be readily scraped off with a knife, and when examined microscopically was seen to be composed of cells. When magnified 350 diameters the cells were observed to be elongated, and apparently a specially modified columnar epithelium.

When seen in profile the free end was somewhat club-shaped, whilst the deeper end was attenuated into a very slender filament. On a surface view the free ends were polygonal and closely compacted together. The arrangement of these cells was readily seen, not only in portions of the membrane scraped off from the chorion, but *in situ* on the chorion itself, where they were observed to form a distinct pavement, not continuous however, over the whole surface of the chorion, as patches, often of considerable extent, had been removed. These cells are to be regarded as the epithelial layer of the chorion modified into a layer of elongated club-shaped cells. Obviously they cannot be regarded as the epithelial cells of the uterine mucosa shed along with the chorion, for if they had been uterine in origin their club-shaped ends would have been in contact with the chorion, and their attenuated ends would have been free, whereas the reverse was the case.

In possessing a covering of elongated epithelium cells on the free surface of the chorion the Eland presents an arrangement which generally resembles the description given by M. A. Dastre in the rabbit, sheep, and pig.[1] In the pig, however, these cells terminated at the deep attached end in a plane facet, and not in an attenuated extremity as in the Eland; moreover, in the pig the cells were uniformly cylindrical, and not swollen out into a club-shaped extremity. Their form in the Eland is not unlike that of the epithelial cells on the chorion of the rabbit, as figured by M. Dastre in his Plate VIII. fig. 4.

I did not observe any white, or brown, or yellowish bodies connected to the amniotic investment of the cord, such as is the rule in the Ruminantia; but it should be stated that this investment was so much torn away that only fragments of it could be seen. Neither did I see such bodies connected with the wall of the sac either of the amnion or allantois.

From the above description it will be seen that the eland-antelope agrees with the other hollow-horned ruminants that have been described, in possessing a large number of cotyledons (caruncules) on the outer surface of its chorion, so that along with them it must be classed amongst the *Polycotyledontophora* (Garrod).

[1] *Annales des sciences naturelles*, Zool. tome iii. 1876.

NOTES ON THE DISSECTION OF A SECOND NEGRO.

By Professor TURNER, M.B., F.R.S.

IN the last volume of this *Journal*, p. 382, I gave an account of a number of variations observed in the dissection of a Negro. I propose now to record some observations on the body of a second Negro, aged 44, subsequently dissected. I gave special instructions to Mr G. S. Brock, Assistant Demonstrator of Anatomy, to note down all the variations met with, and I have incorporated his notes in the following description:—

Muscular System.—The left *zygomaticus major* blended at its origin with the outer fibres of the orbicularis palpebrarum, which curved further outwards than usual. The left *biceps*, in addition to its usual origin from the scapula, had two heads of origin from the humerus. The larger arose from the inner surface of the shaft for 3 inches below the teres major and close to the attachments of the coraco-brachialis and brachialis anticus. The smaller arose from the small tuberosity and from the bottom of the bicipital groove, external to the insertion of the latissimus dorsi. Both the humeral heads joined the fleshy belly belonging to the long head. From the tendon arising from the bottom of the bicipital groove a fibrous band proceeded, which joined the tendon of insertion of the coraco-brachialis. On the right side the lower humeral head was also present, but not the arrangement connected with the bottom of the bicipital groove. The *palmaris longus* was absent in both arms, a not uncommon occurrence in the white races. The *flexor longus pollicis* derived its rounded coronoid origin partly from the front of the coronoid process and partly from the internal condyle of the humerus. The *flexor sublimis* was connected to the flexor profundus by an intermediate tendon. The right *plantaris* was represented by an extremely narrow tendon, formed above by the junction of two still narrower slips, attached, the one to the posterior ligament of the knee-joint close to the internal femoral condyle, the other to the general aponeurosis of the leg, about 2 inches below the inner tuberosity of the tibia, and near the inner border of

that bone. The band thus formed was without a muscular belly, but passed down the back of the leg in the course of the plantaris, and ended by blending with the deep fascia of the leg about 2 inches above the ankle. The right *flexor longus hallucis* sent slips to join the tendons of the flexor longus digitorum to the second and third toes. The tendon of the right *flexor brevis digitorum* to the little toe ended in the long flexor tendon to the same toe. No *peroneus tertius* was inserted into the fifth metatarsal bone, but the long extensor of the toes gave off a tendon to the base of the fourth metatarsal bone. A right *abductor ossis metatarsi minimi digiti* was present.

Vascular System.—In the left arm no *superficialis volæ* was observed. The *superficial palmar arch* was completed by the ulnar anastomosing with the arteria radialis indicis, which was itself irregular, being derived from the arteria princeps pollicis. The arch gave origin to only two *digital* arteries; the inner digital, after supplying a branch to the ulnar side of the little finger, bifurcated to supply the adjacent sides of the little and ring fingers; the outer digital gave origin to the arteries which supplied the adjacent sides of the ring and middle, and middle and index fingers.

The right *ischiatic* artery passed through the sciatic foramen as two branches, between which was situated the pudic artery; all three pierced the great sciatic nerve. Left side was normal. The right *profunda femoris* gave origin to a vessel corresponding to the transverse branch of the external circumflex, whilst the circumflex arteries proper arose from the femoral. On the left side the circumflex arteries were normal in origin, except that the ascending branch of the external circumflex arose from the femoral a little below Poupart's ligament.

Two Thoracic Ducts.—Lying on the vertebral column, one on either side of the descending aorta, were two thoracic ducts, and quite separate from one another at their lower ends, and indeed all the way up the thorax as far as the root of the neck, where they joined to form a common trunk. They were dilated below into two distinct receptacula chyli, which were situated on the first lumbar vertebra, one to the right, the other to the left of the aorta, and received the lymphatics of that side of the body to which they respectively belonged. Each receptaculum was

¼ inch in diameter and 1½ inch in length. The right duct corresponded in its course to the normal vessel passing behind the arch of the aorta to reach the root of the neck, while the left duct traversed the thorax on the left side of the aorta, joining the right in the neck. Both pursued a tortuous course, and, when dissected out and straightened, measured, including receptacula, 15¼ inches. Unfortunately, the termination of the duct had been inadvertently removed in the dissection of the neck.

Nervous System.—In both upper limbs a large branch of communication passed between the median and musculo-cutaneous nerves about the middle of the upper arm. The left frontal nerve bifurcated near its origin from the ophthalmic, one branch passed along with the artery through the supra-orbital notch, the other through a special foramen in the orbital border of the frontal bone ⅜ inch to the outer side of the supra-orbital notch. The left great sciatic nerve bifurcated on a level with the external condyle of the femur. A well-marked gangliform enlargement, especially large on the right side, was on the great splanchnic nerve.

The sigmoid flexure of the colon was greatly enlarged, measuring 3 feet in length and 16 inches in circumference at its widest part. There was no obstruction in the rectum.

None of the variations in the nervous and arterial systems present special features of interest, as they have all from time to time come under the notice of myself or other anatomists, although the arrangement observed in the digital arteries is very uncommon.

The duplication of the thoracic duct in the complete form observed in this Negro is evidently very rare, and is to be distinguished from those cases in which a bifurcation of the duct occurs. In the Monro collection in the Anatomical Museum of this University is a preparation in which, in addition to the normal duct, a duct ascends to the left of the aorta. Henle states that in the Museum at Göttingen is a preparation where the duct enters the thorax as two trunks, which join opposite the ninth dorsal vertebra. But Nuhn has described a case which closely resembles the condition observed in the Negro.

No special interest attaches to the majority of the muscular anomalies described, as anatomists of any experience are quite familiar with them, and they are not so numerous as one often

sees in individuals of the white races. The peculiar modification of the plantaris in the absence of its muscular belly and the substitution for it of a fibrous band, and the four-headed biceps are, however, worthy of note.

Although anomalies of the biceps are far from uncommon, more especially the presence of a humeral head arising between the attachments of the coraco-brachialis and brachialis anticus, yet the existence of four heads to that muscle is occasionally seen. In my dissecting room note-book I have kept a record of seven cases that have come under my observation in the white races. In one a third or humeral head arose in the right arm between the coraco-brachialis and brachialis anticus, whilst the fourth head arose in common with the short head from the coracoid, then separating from it formed a distinct belly which joined the tendon of insertion in the lower part of the upper arm; it was separated from the proper short head by a branch of the musculo-cutaneous nerve. Another case, a male, had in the left arm an arrangement closely resembling the above in the origin of the fourth head, but the third head, in addition to its humeral origin, had an accessory origin from the internal inter-muscular septum about 1 inch below the tendon of insertion of the coraco-brachialis. The brachial vessels and median nerve descended immediately above this accessory slip under cover of the third head to the biceps. The right arm possessed only the usual third head. In a boy the right biceps had a third head from the usual place on the shaft, and a fourth head arising in common with the short head from the coracoid. In another subject, a male, the third or humeral head arose in the usual position, whilst the fourth head, which was long and slender, proceeded from the deep fascia of the upper arm, where it was superficial to the tendon of insertion into the bicipital groove of the latissimus and teres. In another male with the usual third or humeral head, a fourth head arose lower down the humerus between the brachialis anticus and inner head of the triceps. It was separated at its origin from the third head by the brachial vessels and median nerve, but in its course it crossed these objects and joined the aponeurotic tendon of the biceps which ends in the aponeurosis of the fore-arm. In another subject, a female, the third head arose by two perfectly distinct fasciculi

from the shaft of the humerus above the attachments of the coraco-brachialis and brachialis anticus, internal to the insertion of the pectoralis major and immediately below the insertion of the teres major; these fasciculi blended with the posterior surface of the belly belonging to the long head: the fourth head arose from the fibrous capsule of the shoulder joint superficial to the lesser tuberosity; it blended with the inner border of the belly of the long head in the lower third of the upper arm. In another female the right biceps had the usual third head, and the fourth arose as a slender fasciculus from the front of the capsular ligament of the shoulder; it blended with the belly of the long head.

I have spoken of the usual third head to the biceps as having its origin from the humeral shaft between the attachments of the coraco-brachialis and brachialis anticus. Professor Macalister, in his catalogue of muscular anomalies, considers that this arrangement occurs as often as once in every 10 subjects, and Mr John Wood saw it 18 times in 175 subjects, a proportion which corresponds closely with my own observations; but cases sometimes occur in which the biceps has a third head arising not in this but in another locality. In my dissecting room notebook I find a record of a third head arising in the left arm of a male from the deep surface of the tendon of insertion of the pectoralis major; of the right arm of a female in which a third head arose from the upper part of the anterior border of the bicipital groove, where it was blended with the pectoralis major; of the left arm of a male, where the third head arose partly from the deep surface of the tendon of the pectoralis major, and partly from the upper end of both the anterior and posterior borders of the bicipital groove, so that it covered over the long tendon of the biceps; of a left arm, in which the long head was divided into two almost equal parts, the one arose from the anterior border of the bicipital groove close to the pectoralis major, the other occupied the groove, and arose from the capsule of the shoulder joint close to the great tuberosity of the humerus; there was no tendon within the joint. From these cases it would appear that the biceps muscle has a tendency to derive a third head from the neighbourhood of the bicipital groove, but this locality is not nearly so common as the humeral shaft between the coraco-brachialis and brachialis anticus.

A NEW ABNORMALITY IN CONNECTION WITH THE VERTEBRAL ARTERY.

By R. J. ANDERSON, M.D., *Demonstrator of Anatomy, Queen's College, Belfast.*

IN a female subject in which a peculiar condition of the vertebral artery existed, the arteries at the lower part of the neck presented some features of interest, and the following notes were made with reference to them:—

On the left side the subclavian artery gives off the following branches:—

The internal mammary, which has its usual place of origin.

In place of the thyroid axis a branch arises from the first stage of the subclavian which divides into two; one of those, the superficial cervical, passes over the scalenus to its region of distribution, giving off previously a branch which has a course, first upwards and backwards and then directly backwards between the transverse processes of the fifth and sixth cervical transverse processes. The other branch is the inferior thyroid which has an arched course over the common carotid artery, and is distributed to the lower left part of the thyroid body. This artery gives off a small branch before crossing the carotid.

The superior intercostal gives off a small branch, the representative of the profunda cervicis, which terminates at the lower part of the neck, its place being supplied by the branch of the superficial cervical mentioned above, a not unusual occurrence.

The posterior scapular arises from the first stage of the subclavian and pierces the middle scalenus. A small offset is given by this artery to the scalenus medius before its passage through the muscle.

The suprascapular is derived from the anterior part of the third stage.

The most remarkable arterial deviation amongst the foregoing was that of the inferior thyroid, which was larger than the superior thyroid of the same side. A case of the presence of two thyroid arteries is mentioned by Quain,[1] one of which passed

[1] See Quain, *Arteries*, p. 170; Henle, *Handbuch der Gefässlehre*, pp. 364, 365.

in front of the common carotid. Cases are mentioned of the inferior thyroid of the left side commencing from the left subclavian and taking this course, and of the arteria thyroidea arising from the suprascapular and having a similar course.

The left vertebral arises from the arch of the aorta, between the origins of the carotid and subclavian; one-sixth of an inch above its origin it divides into two branches. The posterior, the larger, ascends to the foramen in the transverse process of the fifth cervical vertebra which it enters. In its course to reach the foramen it gives off a small branch from its inner side that is distributed to the connective tissue and muscles in front of the cervical vertebræ. The anterior branch, smaller in size, has a more prolonged course. It ascends in front of the posterior branch, almost completly obscuring it, and unites again with the latter between the third and fourth cervical transverse processes. Thus the vertebral artery is double from a point close to the aorta to the space between the third and fourth cervical vertebræ.

This abnormality in the condition of the vertebral artery may be accounted for by supposing this artery to give off originally the ascending cervical artery, whose branches are ultimately replaced by other arterial twigs, and a small anastomotic twig becomes an anastomosary branch. This origin of the ascending cervical artery is however extremely rare.

An explanation of the abnormality may be sought for in the fact that the inferior thyroid is an occasional branch of the vertebral in the case figured by Quain. This artery has, however, a high origin from the vertebral. If this be the case, and obliteration of the inferior thyroid from the point of origin will reduce the case to the foregoing, and changes similar to those mentioned in the last paragraph may take place. An explanation in this manner is favoured by the fact of the thyroid artery arising from the subclavian and crossing the common carotid, which does not differ much from the arteria thyroidea ima noted by Gruber, which had an origin from the suprascapular.[1]

This abnormality may be accounted for by supposing that one or both branches had an origin from the subclavian originally. Then the case might be explained by supposing several vertebral

[1] Henle, *op. cit.* p. 255.

arteries to exist, more than one to remain pervious. This explanation, given by Quain with reference to a double origin of the vertebral from the subclavian, or the subclavian and aorta combined, would thus apply to this form. The anterior in this case might be regarded as an accessory vertebral artery.

As the abnormalities of the arteries in the right side of the neck are interesting when taken in connection with the foregoing they are here recorded.

The internal mammary arises from an elevation situated in the anterior and inferior part of the subclavian artery, and common to this artery, the suprascapular and superficial cervical.

The superficial cervical, arising from the upper part of the elevation, gives off the ascending cervical and a small thoracic branch that reaches the thorax by passing beneath the subclavian artery.

The suprascapular arises between the foregoing and the internal mammary.

The superior intercostal has its usual origin and distribution.

The vertebral has two roots, the smaller, which at its origin occupies the usual place of the vertebral, ascends to the seventh cervical transverse process, whose foramen it enters. The larger root arises from the subclavian close to the origin of the latter from the innominata; thus the innominata presents the appearance of an axis; the artery ascends to the fourth cervical transverse process and there unites with the other root, which has ascended through the foramina below this point. The artery formed by the junction ascends in the usual position.

This condition of the right vertebral artery is regarded by Mr Quain as very rare, the only case recorded being one in which these roots of origin occurred on the right side. Other observers, however, recognise it as an occasional case of abnormality.

To complete the list of abnormalities on the right side, the origin of the posterior scapular from the third stage, and the presence of an arteria thyroidea arising from the front of the innominata near its termination may be noted.

CASE OF DEVELOPMENT OF WOOL ON THE CORNEA OF A SHEEP. By J. G. Garson, M.D., *Royal College of Surgeons of England.*

In the last number of this *Journal*, Mr G. E. Dobson, M.B., described a case of development of hair on the cornea of a bull-terrier dog. Such a growth is, as he remarks, strong evidence of the similarity of development of the skin and the cornea. His case is not, however, unique, as Professor Flower has directed my attention to a specimen of a similar character in the museum of this college, presented by J. C. Chaytor, Esq., in 1870, which illustrates the same fact. The preparation, numbered 373 in the Catalogue of the Teratological Series, is one in which there is a lock of wool growing from the cornea of the right eye of a sheep. The history received with the preparation was, that when the animal, which was the second cross from a blackfaced moor sheep by a Leicester tup, was being shorn, the shearer observed a lock of wool growing from its eye, which he cut off close to the eyelids. The lock, however, soon began to grow again, and at the time the sheep was killed (when one and a half years old) had attained the same length as it was before the shearing. As the eye has been removed from the skull, and the conjunctiva and muscles cut short, the relation of the eyelids to the anterior surface of the globe cannot be seen. The preparation shows at the outer canthus, and superiorly a projection, resembling a mole of rounded form, measuring about 5 mm. in diameter, situated along the edge of the cornea. From the top of this springs a lock of wool, some of the fibres of which are as long as 6 c.m. The tumour or mole is of a brown colour, more deeply pigmented at some points than at others, so that it presents a mottled appearance. On account of the size and position of the growth, the cornea could only have been partially covered by the upper eyelid. Probably the animal would have acquired the faculty of rolling its eyeball downwards till the tumour rested upon the lower eyelid. This would allow the upper eyelid to fall farther down, and so cover the greater part of the cornea. The vision of the affected eye would not have been interfered with to any great extent, although its field must have been considerably restricted externally. There does not seem to have been any ulceration of the cornea produced by irritation of the wool, as the surface is perfectly smooth and even.

Notices of New Books.

ANATOMICAL AND ZOOLOGICAL RESEARCHES: COMPRISING AN ACCOUNT OF THE ZOOLOGICAL RESULTS OF TWO EXPEDITIONS TO WESTER YUNNAN. By JOHN ANDERSON, M.D. London, 1878.

IN the year 1868, and again in 1875, the Government of India despatched an expedition to explore the province of Western Yunnan, with the object of inquiring into the trade routes which proceed from Bhamô to China, to report on their capabilities for commerce, and to collect information on the resources of the country through which the routes passed. Dr Anderson was appointed to act as Naturalist and Medical Officer to both these expeditions. Notwithstanding the many difficulties thrown in the way by the hostility of the native tribes and the Chinese, who in the second expedition attacked the Mission when only three days' march beyond the frontiers of Burmah, Dr Anderson has succeeded in making a considerable collection in illustration of the fauna of this district. The zoological and anatomical results of the expedition are recorded in the two large and handsome volumes now before us. One of these volumes, extending to nearly 1000 pages, is the text, whilst the other contains 81 large quarto plates, a considerable proportion of which are coloured.

It would be out of place in this *Journal* to enter into any lengthy analysis of the purely zoological part of this work, either as regards the determination of species or the geographical distribution of the various animals collected. But there is so much that is of value and interest to the anatomist, both in the text and plates, that some account of Dr Anderson's observations will, we think, prove satisfactory to our readers. It may be the more advisable to do this, as from the size and cost of the work its circulation will doubtless be somewhat restricted.

One of the most important chapters is an elaborate monograph on the fluviatile Cetacea of the Irawaddy and the Ganges—*Orcella fluviatilis* and *Platanista gangetica*—and of the round-headed dolphin, *Orcella brevirostris*, which frequents the estuaries of the Ganges and Brahmaputra. The description of the structure of these animals is much more complete than had previously been recorded. As some of the specimens obtained were gravid females, Dr Anderson has also enjoyed the opportunity of studying their placentation. We shall begin by giving an account of his researches on the uterus and fœtal membranes.

In the uterus of an almost mature fœtal *Orcella*, the uterine glands were absent, but in the uterus of a fœtal *Platanista* they were almost as well developed as in the unimpregnated uterus of the adult, in

which each gland depended in a highly-branched manner by a single tube from an orifice in the layer of cylindrical epithelium, situated in a slight depression of the mucosa. In the gravid uterus of *Orcella*, the glands formed a dense layer of tortuous branched tubes subjacent to the layer of crypts, in which the villi of the chorion were lodged, and a similar gland layer existed in the gravid uterus of *Platanista*. In *Orcella* the free surface of the gravid mucosa possessed multitudes of minute recesses or crypts, interspersed amongst which were numerous bare spots, in the centre of which was situated the mouth of an utricular gland. In *Platanista* a similar series of bare spots also existed, having a similar relation to the mouths of the utricular glands. These bare spots are therefore in *Orcella* and *Platanista* equivalent to the bare spots in the pig (Ercolani, Turner), lemur (Turner), intercryptal areas in the mare (Ercolani, Turner), and to similar bare spots which Dr Anderson has himself observed in the uterine mucous membrane of the tapir and camel.

The chorion of *Orcella* was studded with vascular villi, the tufts of which varied in size, some being low and closely set, others being longer and arborescent. A linear bare patch, 6½ inches long, was on the chorion where the vessels entered, also one on the apical part of the left horn corresponding to the mesial septum, one opposite the left Fallopian tube, but none was seen opposite the right tube, nor on the part of the chorion opposite the os uteri. Smooth non-villous spots were also scattered over the surface of the chorion, much more numerous on the left pole than on the right. In *Platanista* the villi were diffused over the chorion, which possessed, however, an elongated linear bare patch 19½ inches long, which stretched from within 5 inches of the left pole, to within 17 inches of the right pole of the chorion. A non-villous patch corresponded to the left pole of the chorion, but none was seen opposite the right Fallopian tube. Small circular smooth patches were also scattered generally over the surface of the chorion, more especially on the left horn. These observations by Dr Anderson supply additional examples in illustration of the accuracy of the view taken by Ercolani in his "Memoirs" in the *Bologna Transactions*, and by Turner in this *Journal*, vol. x., that the uterine glands have no necessary relation to the crypts in the gravid uterus for the lodgment of the villi, and that in many animals the glands open on definite smooth patches on the surface of the uterine mucous membrane quite distinct from the crypts.

The fœtus of *Platanista* was situated in the left horn, the head lying with the tip of its snout close to the orifice of the left Fallopian tube. In *Orcella* the fœtus was also in the left horn, and with its snout in relation to the left tuba. In having the snout directed away from the os uteri, these specimens differed from the gravid uteri of Orca and the Narwhal described by Turner, and of Globiceps described by Van Beneden, in which the snout was directed to the os uteri. The surface of the umbilical cord, both in *Orcella* and *Platanista*, was studded with numerous small elevated bodies similar to what have been described by various anatomists in other species of Cetacea. Sac-

like dilatations of the umbilical arteries are described as occurring at regular intervals, and communicating with each other by narrow channels. These dilatations are obviously of a similar nature to those described by Hyrtl, Berger, and Ewart in the arteries of the human umbilical cord. (See this *Journal*, January 1878.)

It would exceed the limits of our space to enter as fully into Dr Anderson's description of the other viscera of these Cetacea as we have done with regard to the gravid uterus, but we may give a brief statement of his observations on the stomach. "The stomach of *Orcella*," he says, "consists of three cavities and of an intervening narrow funnel-shaped channel between the second and third sacs." In *Platanista* the stomach "consists chiefly of two large sacs placed side by side, opening into each other by a common orifice at the termination of the œsophagus. The first or left cavity is perfectly simple, but the second presents a sacculation in the right wall of its fundus; this leads into a short narrow passage or channel which conducts to the third cavity, this latter being about one-eighth the capacity of the others." The dilated sac which follows his third cavity, both in *Orcella* and *Platanista*, he considers to belong to the small intestine, and names it the duodenal sac. It will be observed that the author does not regard the space between his second and third cavities as a compartment of the stomach, but as merely a channel of communication between his second and third compartments. This mode of interpreting the space in question accords with that followed by Murie in his account of the stomach of *Globiocephalus*, but not with that advocated by Turner in this *Journal*, vols. ii. iii., in which this so-called passage is described as a small but distinct compartment of the stomach.

Dr Anderson describes large vascular channels penetrating the walls of the stomach of *Orcella*, and corresponding in most respects in structure with the "moniliform tube" found by Turner belonging to the vascular system of the intestine of *Balænoptera Sibbaldii*. He also points out the presence of a peculiar gland connected with the stomach of *Orcella*, which closely corresponds in structure with a gland in the lung both of that animal and of *Platanista*. The brain of *Orcella* was not obtained in a fit state for examination, but that of *Platanista* is both figured and described. Many observations are made on the skeleton of *Orcella*, and an exhaustive description, with numerous figures, is given of the skeleton of *Platanista*.

Another genus of Mammals, the anatomy of which has been specially studied by our author, is the genus *Manis*, and he points out the anatomical characters by which *M. pentadactyla*, *aurita*, and *javanica* are to be distinguished from each other. He was so fortunate as to secure a gravid uterus of *M. pentadactyla*, with a fœtus in the right horn. The two horns of the uterus possessed a similar relation and form to the corresponding structures in *Platanista* and *Orcella*. The chorion was covered with villi impacted in the spongy tissue of the wall of the uterus. He recognised a broad non-villous band on the chorion resembling that described by Sharpey in the only specimen of the placenta of *Manis* which had previously been examined. This

band, as in *Orcella*, *Platanista*, and the Tapir, corresponded to the course of the great vessels of the cord. He also describes a non-villous area opposite the os uteri, as well as in relation to the mouths of the Fallopian tubes. About eight bare tracts diverged from the region of the os along the sac of the chorion. Although the uterine mucosa was generally cryptose for the lodgment of the villi, yet non-cryptose areas corresponded to those parts of the chorion where villi were absent. He did not succeed in finding utricular glands, although both Sharpey and Turner had seen these structures in Sharpey's specimen.

Another valuable section of the work is the chapter on the *Reptilia* collected, more especially the Chelonia, and along with the tortoises from Western Yunnan the author has described a few Indian species elsewhere obtained. His object has evidently been, by giving a precise anatomical description of these specimens, to put on a more definite basis the classification of these animals, and to rescue them from the state of confusion into which they have been thrown by some writers.

We may congratulate Dr Anderson on the completion of this splendid work, in which he has reared a monument to his industry as a collector, to his research and descriptive powers as an anatomist, and to the skill with which he has brought his anatomical knowledge to bear on the discrimination of specific characters.

RECHERCHES SUR LES ENVELOPPES FŒTALES DU TATOU A NEUF BANDES (*DASYPUS NOVEMCINCTUS*). By M. ALPH. MILNE-EDWARDS. (*Annales des Sciences Naturelles*, VI. Series, Tome VIII., No. IV.

IN this memoir M. Alph. Milne-Edwards has communicated some very remarkable observations on the placentation of the Armadillo. The gravid uterus he examined contained four fœtuses. When the uterine cavity was opened a single pear-shaped sac was exposed, which appeared to be the chorion of a single embryo. The superior pole of the chorion was thin and non-villous, but its median part was thick, spongy, and vascular, and extended in a zonary manner around the chorion. The borders of this zone were scooped out into four lobes with rounded contours. The part of the chorion below this zone was thin and delicate, nevertheless some vascular villi could be seen, which diappeared towards the pole corresponding to the neck of the uterus. The zonary placenta received four groups of arteries and veins at its upper border, each group being distributed to one of its four lobes, so that this zone, instead of being as in other zono-placentalia, a single organ, was really composed of four discoid placentæ fused together by their lateral borders.

When the chorion was opened into, four fœtuses were found in its interior, closely packed together, but enveloped each by its own amnion. The amniotic sacs were very distinct at the lower part, but they were fused together at the end situated above the placental zone.

The funis of each embryo was very elongated, not twisted into a spiral, and was contained within the amnion. When the development is but little advanced the amniotic sacs are distinct and complete, but in the latter stages of gestation, they become fused together at their points of contact, so that the amniotic sacs tend to communicate with each other.

The allantois is but little developed and no trace of it can be seen externally, but if the cord be dissected its remains appear as a small fibrous band in relation with the urinary bladder. The urachus was distinct. The chorion was readily detached from the uterine wall; the connection between its villi and the corresponding uterine surface was slight; the structure seemed to indicate the presence of a decidua, but on this point M. Alphonse Milne-Edwards could not speak with certainty, for the specimen had been for some time preserved in spirit.

The inclusion of four fœtuses in a common chorion is a most remarkable fact in the placentation of this species of Armadillo, and one for which it is not easy to find a rational explanation; it can only be solved when the development of the ovum of this animal has been followed out from its commencement. The author concludes with a statement, similar to that made by Turner in this *Journal*, vol. x. p. 786, that there is no uniformity in the mode of placentation of the Edentata.

DIE LEITUNGSBAHNEN IM GEHIRN UND RÜCKENMARK DES MENSCHEN AUF GRUND ENTWICKELUNGS-GESCHICHTLICHER UNTERSUCHUNGEN. DR PAUL FLECHSIG. Mit 20 Lithographirten Tafeln. Leipzig, 1876.

(*Abstract by* DR W. J. DODDS.)

THIS volume forms one of the most important contributions of recent times to the anatomy of the central nervous system. It is full of new matter. It opens out to us two new methods of investigating the subject, viz., the *macroscopic* method of the development of the medulla-white, and the *microscopic* method of the development of the medulla or white substance of Schwann. The results attained by these methods we shall now endeavour to unfold.

The first part of the work is on the order of development of the *medulla-white* (mark-weiss), that is, the mature white matter or medulla as distinguished macroscopically from the grey, hyaline, immature medulla. In a fœtus 25 ctm. long, the medulla-white was seen in Burdach's column. In one of 32 ctm., in the upper cervical portion of the anterior column, in the posterior longitudinal fasciculus of the medulla, and in the oculomotor, facial, and auditory nerves. Somewhat later, in the outer parts of the remaining portions of the anterior column, adjoining the anterior cornua, in the anterior half of the lateral column, the fillet, the posterior peripheral part of the

lateral column, the anterior part of the internal motor field of the oblongata, portions of the restiform body up to the superior vermiform process, the ascending root of the lateral mixed system, the 6th, 4th, 3rd, and 9th nerves. In a 38 ctm. fœtus, a portion of the posterior cerebral commissure showed the medulla-white appearance. In a fœtus of 44 ctm., the medulla was fully developed in the rest of the superior vermiform process, in the flocculus, the nucleus dentatus, the crura cerebelli and corpora quadrigemina, the brachia conjunctiva postica, the whole of the posterior commissure, and in portions of the internal capsule. In a fœtus 46 ctm. in length, the medulla-white was seen as a small strip in the crusta; it was also seen in the pons, in the laminæ medullares of the lenticular nucleus, and in a tract extending from the internal capsule and lenticular nucleus to the upper part of the ascending parietal convolution. In fœtuses from 49 to 51 ctm. long, the whole of the medulla uniting the uppermost parts of the ascending convolutions with the internal capsule and lenticular nucleus was fully developed, as also a strip stretching from internal capsule to occipital lobe. At this period the grey, hyaline medulla was no longer to be seen in the spinal cord and the greater part of the cerebellum, and the pyramids began to assume their mature appearance. A few days after birth the cerebellum and pons showed on traces of immature medulla, and before long the white matter uniting the occipital and temporal lobes with the basal ganglia had lost its embryonal appearance. About three months after birth fully formed medulla was seen in the frontal lobe. But in a child a little less than four months old, the fœtal characters of the medulla still persisted in the second frontal convolution, the anterior part of the temporo-sphenoidal lobe, the fornix, and the portions of the crusta adjoining the substantia nigra. In a child of nine months the development of the medulla was complete in all parts of the central nervous system. We may mention that in every region of the cortex cerebri the projection fibres were first developed, then the fibræ propriæ, then the callosal fibres, and lastly, the association fibres. In fœtuses of equal age the appearances presented by the same portion of medulla are remarkably constant.

Of what significance are these differences in the order of development of the medulla-white? Do the tracts so marked out represent what may be called systems of fibres? Flechsig answers that in the main they do. He shows that in the spinal cord and medulla oblongata the course of development of the naked eye appearance, known as medulla-white, closely corresponds with the development of the medulla as observed by the microscope (see below). The importance of this fact is seen in relation to the anatomy of the cerebrum. The results of the former method will serve as a guide in the elucidation of the structure of this most complex region by the more minute and difficult method of the microscopic development of the medulla.

The second part of the work is on the microscopic development of the white matter of the spinal cord and medulla oblongata. The development of individual fibres is best seen in the pyramidal strands. In a

fœtus 25 ctm. long, the pyramidal fibres are represented by exceedingly delicate fibrils embedded in a pale, finely granular matrix; a few cells, in part resembling connective tissue elements, in part lymph-corpuscles, are also seen. At a later period, dark fatty granules appear in the matrix, and the number of cells is very largely increased; both cells and granules are arranged in more or less longitudinal rows. Still later fatty granules are observed in many of the cells, and the matrix presents the appearance of a longitudinally striped, highly refractile mass, which has all the characters of medulla. Flechsig agrees with Jastrowitz, that the fat of the matrix is not carried from the blood by the wandering granule-cells, but is formed *in loco*. The function of the granule-cells is unknown. It may be that they bear away the superfluous fat that is produced during the formation of the medulla, or that they absorb the fat of the matrix, returning it transformed into medulla; or lastly, that they have nothing whatever to do with the medulla, this being a purely nervous element formed from the axis-cylinder.

All the fibres do not receive their medullary investment at the same time; on the contrary, some groups of fibres have a complete coating of medulla months earlier than others. The fibres first invested with medulla are those of the ground-bundle of the anterior column; then follow in order those of the ground-bundle of the posterior column (Burdach's column), the mixed zone of the lateral column, the limiting layer of the lateral column, Goll's column, the direct cerebellar tract, and lastly, the fibres of the pyramidal tracts. In the oblongata, the order of development of the medulla is as follows:—First, in the posterior longitudinal fasciculus, then successively in Burdach's column, in the ascending root of the lateral mixed system, the ascending root of the 5th nerve, the antero-external bundles of the formatio reticularis, the inner division of the cerebellar peduncle, a portion of the corpus restiforme, the great mass of the formatio reticularis, the inter-olivary fibres, another portion of the restiform body, and lastly, in the pyramids and a third portion of the restiform body.

The question arises—Have these groups of fibres any special significance? Do they represent a *natural* division of the cord and medulla oblongata? In the case of the pyramidal tracts they do; for, as Flechsig shows, these tracts consist exclusively of fibres which form a direct communication between the grey matter of the cord and the corpus striatum or cerebral cortex. In other words, these tracts constitute what may be termed a distinct *system* of fibres. The direct cerebellar tract and Goll's column also form distinct systems; indeed, all the groups given above are either systems of fibres complete in themselves or combinations of several systems. The order of development of the medulla furnishes us therefore with a systematic division of the white matter.

The question immediately suggests itself, Are not the axis-cylinders themselves laid down in successive groups? is not their order of development also a systematic one? In the case of the pyramids,

the anterior column ground-bundles, the direct cerebellar tracts, and Goll's columns, Flechsig shows that a constant period of four to four and a half months intervenes between the first appearance of axis-cylinder and its complete investment with medulla; and he argues that as the latter process is systematic, it is probable the development of the axis-cylinder is also systematic. Direct observation confirms this, for the pyramids, Goll's columns, and the anterior spinal roots, when first formed, are distinct from all other bundles of axis-cylinders.

The axis-cylinders of the posterior longitudinal fasciculus and of the ground-bundle of the anterior column appear as early as the fourth week of fœtal life; those of the ascending root of the 5th nerve are seen at the sixth week; those of the direct cerebellar tract and of Goll's column about the ninth week; and those of the pyramidal tracts not until the fifth month. The following is a generalisation of the order of development of the fibres:—(1) fibres running between central grey matter and periphery; (2) fibres running between different parts of central grey matter; (3) fibres running between central grey matter on the one hand and the cerebellum and ganglia of the tegmentum on the other; and (4) fibres running between ganglia of crusta (perhaps also cortex cerebri) and central grey matter. It will be observed that the fibres necessary for simple reflexes are developed first, those for voluntary motor acts last.

To the question, What conditions this successive development of tracts of fibres? no definite answer can be given. We should expect that it would depend on the successive ripening, so to speak, of the groups of mother-cells from which the tracts arise, the cells of the grey matter having an order of development parallel to that of the axis-cylinders and medulla. At this point, Flechsig's research touches on the subject of Boll's and Eichorst's investigations. Boll, for example, has shown that, while the cells of the spinal cord of a chick are distinguishable on the third day, those of the cortex cerebri are not seen till the seventh day. A full inquiry, however, into the successive development of the cells of the grey matter has yet to be made.

The mode of origin of the pyramidal strands is discussed. That they are formed *in loco*, from cells pre-existing in the locality, is improbable on several grounds. (1.) They appear with extraordinary rapidity, *e.g.*, at the beginning of the fifth month the pyramids are not to be seen, but by the middle of the month they form one-ninth of the transverse section of the medulla oblongata. (2.) Notwithstanding the great variations in the distribution of the pyramidal strands, those belonging to one pyramid (see sequel) are equal to those belonging to the other. These difficulties vanish if we hold that the pyramids and pyramidal strands grow from above downwards. Further support is lent to this view by the following considerations:—First, actual observation has shown that the medulla of these fibres is developed from above downwards, and the formation of the medulla we have seen, is in all probability but a repetition of that of the axis-cylinder; secondly, in cases of acranus, the pyramids and pyramidal

strands are awanting; and thirdly, the outer conformation of the cord sometimes indicates that the pyramidal strands of the anterior column are simply an annex to the ground-bundle. The decussation of the pyramids can be explained consistently with the downward growth of the fibres. According to Flechsig, the fibres simply follow the direction of least resistance (for particulars see *op. cit.*, p. 203).

A chapter is devoted to the subject of secondary degeneration considered as an aid to the anatomy of the central nervous system. The results are given of an examination of three cases of ascending, and nine cases of descending degeneration. Flechsig finds that the divisions of the spinal cord and medulla oblongata, as mapped out by secondary degeneration, coincide with those determined by the development of the medulla. He confirms Türck's observation that in cases of ascending degeneration the direct cerebellar tracts and Goll's columns are the only bundles affected. The pyramidal strands of the anterior column do not always arise from the same portion of the lenticular nucleus, showing that the fibres of these strands are not always the same.

The third part of the work gives the anatomical results of the investigations into the development of the medullary substance. We shall merely note some of the more important conclusions arrived at.

The white matter of the cord is divided into the following seven tracts or strands :—

(1.) *The pyramidal tracts.*—The fibres of the pyramidal on reaching the decussation take one of two courses; they either cross to the lateral column of the opposite side, or pass downwards in the anterior column of the same side. Thus the pyramidal tract of the lateral column consists of crossed, that of the anterior column of uncrossed, fibres. The proportion of crossed to uncrossed fibres is very variable in different cases. There may be (*a*) complete decussation of both pyramids, all the fibres crossing to the opposite lateral columns; (*b*) complete decussation of one pyramid, incomplete of the other; or (*c*) incomplete decussation of both pyramids. In this last case the anterior columns may contain from 90 per cent. downwards of the pyramidal fibres. Further, the distribution of the pyramidal fibres may be symmetrical or unsymmetrical; in other words, the pyramidal tracts of the anterior or lateral columns of one side may be equal or unequal to the corresponding tracts of the opposite side. But no matter what the distribution of the pyramidal fibres is, the sum of the fibres belonging to the pyramid of one side is equal to the sum of the fibres belonging to the pyramid of the opposite side—that is, the left anterior plus the right lateral tract is equal to the right anterior plus the left lateral tract. This is the law of the compensatory relation of the pyramidal strands. In the few cases in which this rule does not hold good, the pyramids themselves are found to be of unequal size. The mode of division of the pyramids is so variable that no type or standard arrangement can be fixed. Most frequently, however, there are four pyramidal tracts, one in each anterior and lateral column. The anterior tract generally contains

from 3 to 9 per cent. of the pyramidal fibres. These variations have an important bearing on questions of pathology and clinical medicine. For example, the atrophy of the antero-lateral columns after cases of the loss of a limb, may, for anything we know, have been in reality cases of asymmetry, for hitherto authors have never thought of distinguishing between the two conditions. The same lesion may, in different cases, produce different results—*e.g.*, lesion of one-half of the cord may in one case cause paralysis on one side; in another, paralysis on both sides. Incompleteness in the downward growth of the pyramids, and in their connection with the grey matter of the cord, is probably the explanation of some of the cases of paralysis, defective co-ordination, &c., observed at birth.

The pyramidal fibres of the lateral column run in the posterior half of the column. However slightly developed, they can always be traced as far as the inferior limit of the lumbar enlargement. They are lost in the grey substance between the anterior and posterior cornua. They seem to pass in the direction of the anterior commissure; but that this is their destination is improbable, because the fibres of the commissure are coarse; those of the pyramidal tract fine. At the most, only a few fibres can pass directly into the anterior roots; because (1) in secondary degeneration of the lateral tracts, the anterior roots are intact; (2) the fibres of the anterior roots are medullated when those of the lateral tracts are non-medullated; and (3) the fibres of the roots are coarse, those of the tracts fine. The pyramidal fibres of the anterior column occupy the inner part of the column. They may extend no further than the cervical enlargement, or be found as low as the lumbar enlargement. It is not known whether they decussate in the anterior commissure with the fibres of the opposite side. In the medulla they always form the most external bundle of the pyramid.

(2.) *The direct cerebellar tract.*—The main bundle lies immediately under the pia, external to the lateral pyramidal tract. It is bounded in front by the mixed zone behind by the posterior nerve-roots, and in the lower dorsal, and lumbar region by the lateral pyramidal tract. Other fibres are found scattered through the adjoining systems. They are most numerous in the lower part of the cord; superiorly they are gathered into the main bundle just described. The cerebellar tracts can be distinguished at the level of the third lumbar nerve. In their passage upwards to the restiform body, they continually increase in sectional area, the increase being most marked between the second lumbar and fourth dorsal nerves. Their fibres can be traced to the grey matter in the neighbourhood of Clarke's columns; and though their termination in the cells of Clarke's columns has not yet been demonstrated, such a connection is probable on many grounds. There is no reason to suppose that they are directly continuous with the sensory roots which enter Clarke's columns. Fibres of similar calibre to those of the direct cerebellar tract enter Clarke's columns from the anterior commissure and anterior cornua, but their relation to the cerebellar fibres is not yet known.

(3.) *The limiting layer of the lateral column.*—The relations of

this layer vary at different heights. It is sufficient to say here that it borders the grey matter of the cord, and is surrounded in other directions by the mixed zone, and the lateral pyramidal tract. At the level of the first and second cervical nerves it is pierced by a network of grey matter in connection with the anterior cornua, and thereby broken up into a great number of bundles. In the medulla it is probably represented by that part of the formatio reticularis which lies between the nuclei of the 8th and 9th nerves, on the floor of the fourth ventricle. The termination of the fibres is unknown. They pass in the direction of the anterior commissure, but appear to bend sharply forwards and outwards, without entering it; they are apt to be confounded with the lateral pyramidal fibres. In the cervical enlargement, and in the dorsal and upper lumbar portions of the cord, bundles of longitudinal fibres are found between this layer and the grey matter, and also embedded in the adjacent grey matter. These belong in part to the cerebellar tract, and in part to the posterior nerve-roots, from which they arise directly. In the upper cervical region, the roots of the accessorius are the homologues of these bundles.

(4.) *The mixed zone of the lateral column.*—This zone contains both coarse and fine fibres—the former predominating in the lower part of the cord; the latter in the upper cervical part. Of the coarse fibres, some pass to the anterior nerve-roots (*via* the anterior cornua), others to the anterior commissure, others again to the anterior cornua; the connection of these last with the ganglion-cells has not been made out. The fine fibres lose themselves in the fine plexus of the grey matter. Superiorly, some of the fibres seem to re-enter the grey matter. The greater number of them, however, pass on to the medulla oblongata, where they are found in the anterior part of the formatio reticularis, behind and external to the olivary body; indeed, a few fibres probably enter the body. The distinction between limiting layer and mixed zone is not recognisable in the lumbar enlargement.

(3.) *The ground-bundle of the anterior column.*—This consists of the anterior column minus the pyramidal tract. Its fine fibres spring from the anterior cornu of the same side; its coarse fibres from the anterior nerve-roots and grey matter of the opposite side by way of the anterior commissure; a few also from the anterior cornu of the same side. Superiorly it is for the most part continuous with the posterior longitudinal fasciculus of the oblongata; a few fibres, however, go to the inner part of the motor field. We may mention that Flechsig's ground-bundle, mixed zone, and limiting layer together constitute the "zones radiculaires antérieures" of Pierret and Charcot.

(6.) *Goll's column.*—This fasciculus comprises that portion of the posterior column which bounds the posterior median fissure. It is limited externally by a connective tissue septum. It probably extends from oblongata to lumbar enlargement, but developmentally it is only definable in the cervical, and the upper third of the dorsal region. It receives fibres from (*a*) the inner aspect of the posterior cornu, particularly the vicinity of Clarke's columns; and (*b*) the pos-

terior columns and Clarke's columns, by way of the posterior commissure and septum posterius,—whether of the same or the opposite side is not known. The greater part of the fibres end superiorly in the post-pyramidal nucleus of Clarke (the clava, or Kerne der zarten Stränge of authors).

(7.) *The ground-bundle of the posterior column, or Burdach's column.*—This consists of the posterior column minus Goll's column. It varies much in size at different heights, the variations being due to its connection with the posterior nerve-roots. Whether all the fibres are direct continuations of the posterior roots is uncertain; probably some have a different origin. Numerous fibres leave the bundle and pass in the direction of the posterior commissure, the anterior cornu, and the column of Clarke. But many fibres remain and continue onwards to the medulla, where they end for the most part in the nuclei of Burdach's column (Kernen der Keilstränge). It is possible that some of the fibres become fibræ arcuatæ, and terminate in the olivary body.

The seven systems whose anatomy we have briefly described may be divided into two classes,—(1.) Those whose sectional area varies at different parts of the cord with the number of nerve fibres therein arising. This group includes the ground-bundles of the anterior and posterior columns, and the limiting layer and mixed zone of the lateral column. For the most part they spring from the nerve-roots, either directly or after the mediation of grey matter. They are found through the whole length of the cord. They terminate mainly in the ganglion-cells of the formatio reticularis, but also in Burdach's nuclei, the olivary body, and the optic thalamus; in the last two instances it is doubtful whether the connection is a direct one. Some of the fibres are commissural, associating different parts of the grey matter of the cord. (2.) Those whose sectional area continually increases from below upwards. To this set belong the pyramidal tracts, the direct cerebellar tract, and Goll's column. These connect the spinal cord with the cerebrum, the cerebellum, and the post-pyramidal nucleus of the oblongata. They are not found in the lowest part of the cord.

The medulla oblongata is described under the heads of—(1) Pyramids, (2) cerebellar peduncles, (3) internal field of oblongata, and (4) external field.

(1.) The *pyramids* increase in size as they pass upwards. This increase is probably due to the pyramidal strands of the cord being joined by (*a*) fibres of the medulla equivalent to the spinal fibres, (*b*) fibres of the fibræ arcuatæ, and (*c*) fibres of the pons. Hitherto it has been generally held that fibres also pass from the post-pyramidal nucleus (nucleus of Goll's column) to the pyramids by way of the superior decussation. This Flechsig combats on the grounds, first that the fibres of the superior decussation are developed much earlier than those of the pyramids and differ from these in character; second, that a great part of the fibres of the decussation can be actually traced to the neighbourhood of the olivary body; and third, that in certain cases the superior decussation remains intact when the pyramids are

entirely absent. On these grounds the author concludes that the so-called superior decussation of the pyramids has nothing whatever to do with the pyramids. Flechsig has little to say about the central terminations of the pyramids. He states that most of the fibres end in the lenticular nucleus: whether any pass to the caudate nucleus or cortex cerebri directly is doubtful.

(2.) The *cerebellar peduncle* is divided on developmental grounds into an outer portion (corpus restiforme), and an inner. The restiform body is composed of (*a*) direct cerebellar fibres, (*b*) fibres from the region of the olivary body and from the formatio reticularis, and (*c*) fibres from the pyramid. The mode of termination of these fibres in the cerebellum is not described.

(3.) The *internal field* lies between the floor of the fourth ventricle and the pyramid, and is bounded mesially by the raphe, laterally by the root of the 9th nerve. It is made up of the posterior longitudinal fasciculus, the mesial portion of the formatio reticularis, and the inter-olivary tract. The posterior longitudinal fasciculus is, as already remarked, a continuation of the ground-bundle of the anterior column. Anteriorly it can be traced into the vicinity of the posterior cerebral commissure, further forwards it is lost. Meynert's statement that it ends partly in the grey matter of the third ventricle, partly in the ganglion of the peduncular loop, is erroneous. Probably only a few of the fibres of the mesial division of the formatio reticularis are directly continuous with the fibres of the ground-bundle of the anterior column; developmentally they are allied rather to the inter-olivary tract, and the formatio reticularis of the external field. There is a considerable increase in the number of these fibres from below upwards. Deiters' explanation of this—and Flechsig accepts it—is that the new fibres are derived from the large multipolar cells that are scattered through this portion of the medulla; superiorly many of the fibres terminate in the optic thalamus. The position of the inter-olivary tract is sufficiently indicated by its name. It is probable that its fibres do not all belong to the same system: some appear to be connected by means of the superior decussation with the nucleus of Goll's column, others with the olivary body, others again with the ganglion-cells of the raphe. Most of the fibres end in the fillet of the corpora quadrigemina. It is doubtful whether any are directly continuous with the pedunculus substantiæ nigræ.

(4.) The *external field* comprises what is left of one-half of the medulla when the pyramid, cerebellar peduncle, and internal field have been taken away. In it are comprised the region of the olivary body, and the lateral portion of the formatio reticularis. The relation of the former to the spinal cord, Flechsig has been unable to determine. All he can state from his own observations is, that its position in the medulla corresponds to that of the mixed zone of the lateral column and the outer portion of the ground-bundle of the anterior column. The connections of the olivary body with cerebellar peduncle and fillet have been already alluded to. The lateral portion of the formatio reticularis is analogous in its position to the limiting layer

and mixed zone of the lateral column, the fibres of the former passing into the region adjoining the floor of the fourth ventricle, those of the latter into the region adjoining the olivary body. Development teaches us, however, that only a small portion of the fibres are directly continuous with those of the mixed zone. Others are connected with the limiting layer, and others probably with the large multipolar ganglion-cells that lie scattered through these parts. Superiorly the fibres terminate chiefly in the optic thalamus. In all likelihood the formatio reticularis is connected with many other systems through its large ganglion-cells, *e. g.*, with the cerebellar peduncles, the nuclei of Burdach's columns, the nerve-nuclei of the oblongata; at present, however, these connections remain hypothetical.

Attention is drawn to the lateral column nucleus, a collection of cells that appears in the region of the inferior decussation, between the mixed zone and the pyramidal tract of the lateral column, and attains its greatest development at the level of the superior decussation. Some of the fibres of the mixed zone apparently terminate in it.

Viewing the composition of the medulla as a whole, we may divide its fibres into three sets:—(1.) Fibres which are direct continuations of peripheral nerves. Here are included the ascending root of the 5th nerve, the ascending roots of the lateral mixed system (Meynert, the respiratory bundles of Krause), and the posterior longitudinal fasciculus. (2.) Fibres which are in connection with the "specific apparatus" of the medulla. And first, those that are in relation to the ganglion-cells of the formatio reticularis or the cell-groups therein contained. We have, on the one hand, the fibres from the mixed zone and limiting layer of the lateral column, those from the ground-bundles of the anterior and posterior columns (?), those from the nerve-nuclei of the oblongata, and those from the nuclei of Burdach's columns (?); and, on the other hand, the fibres from the cerebellum and the optic thalami. Secondly, those that are in relation to the olivary body. This group comprises fibres from the cerebellum, the corpora quadrigemina (?), and the nuclei of Burdach's columns. Thirdly, those that connect the post-pyramidal nuclei with the spinal cord and corpora quadrigemina, and Burdach's nuclei with the ground-bundles of the posterior columns. (3.) Fibres which connect the spinal cord with the cerebrum and cerebellum. These fibres merely pass through the medulla; they have no termination in it. Under this head are contained the pyramidal fibres, the direct cerebellar tracts, and (?) fibres that run in the formatio reticularis upwards to the optic thalami.

The book closes with a short examination of the bearing of recent physiological experiments on the anatomy of the cord and medulla.

THE CAUSE OF THE HEART'S IMPULSE HISTORICALLY CONSIDERED. By Dr Paul Guttmann, *Teacher in the University of Berlin.*

(From *Virchow's Archiv.*, Bd. 76, 1879.)

The recoil theory, as an explanation of the cause of the heart's impulse, has now for many years been generally adopted, notwithstanding that objections have been made to it. This theory, it is generally believed, was first proposed by Dr Gutbrod; but this is an error. Dr Gutbrod has never himself published anything on the subject. The theory was first announced as Gutbrod's theory by Skoda in 1837 (*Medicinisch Jahrbuch des Oesterreich Staats*, bd. xiii. p. 234). Skoda, in his paper, after discussing several other theories of the cause of the heart's impulse, says of Gutbrod's: "The following explanation of it by Dr Gutbrod, which up to this time has never been published, will, I believe, recommend itself to every one as the true cause." Since then Skoda, in various editions of his book (*On Auscultation and Percussion*), from 1839 to 1864, has adopted this theory, and brought it into general notice.

Dr A. Napier, of Glasgow, has lately called my attention to the fact that a precisely similar explanation of the heart's impulse was proposed in 1825, twelve years before Skoda's publication, by the well-known physician Dr Alderson ("On the Motion of the Heart," *The Quarterly Journal of Science*, &c., vol. xviii., 1825, January, p. 223). Afterwards I found in P. Niemeyer's *Text-Book of Percussion and Auscultation*, a notice that Dr Markham, in his translation of Skoda's work in 1853, had claimed for Dr Alderson the priority in reference to this recoil theory. Notwithstanding this correction, the theory of Dr Alderson has been almost wholly ignored.

To prove the identity of the theories of Gutbrod and Alderson, I will give the very words in which it has been described by Skoda and Alderson.

Skoda says that "the systole movement of the heart downwards, and its pressure against the walls of the chest, are only explicable according to Gutbrod's views. It is a well-known physical law that, when a fluid escapes from a vessel, the equality of pressure produced by the fluid on the walls of the vessel is lost, for there is no pressure at the opening whence the fluid escapes; but at that part of the vessel which is opposite to the opening the pressure is still exerted. This pressure it is which sets Segner's wheel in motion, and produces the recoil of firearms, &c. By the contraction of the ventricles, the pressure which the blood exerts upon the walls of the heart, opposite to the opening whence the stream escapes, causes a movement of the heart in a direction contrary to that of the arteries, and with a force proportionate to the quantity and the velocity of the current of the blood."

On the same physical principles Alderson, in 1825, explained the cause of the heart's impulse. He gives the description and a figure of

the apparatus, called Barker's mill (which is *identical* with Segner's wheel). Barker's mill consists of a cylindrical vessel movable on a vertical axis, at the bottom of which there is a horizontal tube. When the vertical cylinder is filled with water, the water escapes through both the openings on the opposite sides of the horizontal tube, and the difference of pressure thence resulting sets the apparatus in motion. It is moved in a direction contrary to that of the flow of water.

Dr Alderson's words are: "The effect produced is a rotatory motion, arising, not from the resistance given to the issuing fluid by the air (for it would take place in vacuo), but from the want of resistance to counteract the pressure of the fluid against the sides of the horizontal tubes opposite the orifices."

On this principle Alderson explains the cause of the impulse of the heart.

"This," he says, "is the principle I propose making use of to account for the motion of the heart." The mode of action he thus explains: "Let us suppose the aortic orifice to be closed with a plug, retained in its place by the fingers, and that the ventricle be now allowed to contract, it is clear that it will require a certain force to keep the plug in its place—*i.e.*, to counteract the effect of the reaction of the blood arising from the contraction which takes place in a similar portion of the parietes on the opposite side of the ventricle in a contrary direction. If, then, we remove the finger and allow the blood to escape, the reaction on the opposite side of the ventricle remains uncounteracted, and it is by this uncounteracted force that the heart is moved."

This lucid explanation of the recoil theory requires no commentary.

Alderson adds that the direction of the heart's impulse is the resultant of the two forces—the contraction of the two ventricles.

I have considered it a duty to rescue from oblivion the almost forgotten work of Dr Alderson. It is seldom referred to, even in England.[1] In other countries, and especially in Germany, the recoil theory is bound up with the names of Gutbrod and Skoda.

In future, however, if this theory is to retain the name of an author, it must be called Alderson's Recoil Theory of the Heart's Impulse.

[1] Dr Napier, at my request, took the trouble to examine what was said on this point in English literature. He found Alderson's work mentioned in Todd's *Cyclopædia of Anatomy and Physiology*, vol. ii. 1836; in the translation of Skoda's work on *Auscultation*, by Dr Markham, in 1853; and by Dr Hayden's work on *Diseases of the Heart and of the Aorta*, Dublin, 1875.

CATALOGUE OF THE SPECIMENS ILLUSTRATING THE OSTEOLOGY AND DENTITION OF VERTEBRATED ANIMALS (RECENT AND EXTINCT), CONTAINED IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND. By WM. HENRY FLOWER. Part I. London: 1879.

ALL anatomists will hear with satisfaction that a new Catalogue of the magnificent collection in the Museum of the Royal College of Surgeons of England is in course of preparation by the present admirable conservator, Mr Flower. Those who have had to work in that Museum will have experienced the inconvenience that is caused by having to refer to a Catalogue partly in print and partly in manuscript, and they will concur in thanking the Council of the College for the wise resolve to have a new Catalogue prepared, which may fulfil the present requirements of the Museum. But, whilst hailing with satisfaction the advent of a new catalogue, we must not neglect to express our gratitude to the labours of Professor Owen, extending over so many years, for the admirable series of descriptive catalogues which have been up to this time in use.

The volume now before us owes its interest to containing a record of the valuable and extensive series of human crania in the collection of the College. Mr Flower has not, however, given a detailed description of these skulls, but has appended to a brief statement of the locality whence the skull was obtained, a note, where practicable, of the sex, and some of the most important measurements. These measurements have had for their special object the determination of the horizontal circumference of the cranium; its length from the most projecting part of the occiput to the *ophryon*, a point situated immediately above the glabella; its height from the anterior border of the foramen magnum to the point of junction of the sagittal and coronal sutures; its greatest breadth in the parietal region; and its internal capacity; whilst the measurements of the face have been taken so as to determine the height and width of the nose, the height and width of the orbit, the length from the anterior border of the foramen magnum on the one hand to the fronto-nasal suture—the basi-nasal diameter; and on the other to the most projecting part of the upper jaw—the basi-alveolar diameter.

From these measurements the relations of the length of the cranium to its breadth and to its height, the relations between the height and width of the nose and of the orbit, and the projection of the upper jaw have been calculated and expressed numerically. The measurements of the individual skulls have then been collected, reduced to averages in each geographical group, and then tabulated. The characters derived from the measurements are expressed in a nomenclature introduced mainly by M. Paul Broca, which allows of the medium conformation being stated as well as the more extreme forms.

Thus, as regards the important relation of length to breadth, whilst some crania are dolicocephalic, with the latitudinal index below 750; others are brachycephalic with that index above 800; and others again are mesaticephalic with the index from 750 to 800. The nasal index, *i.e.*, nasal width × 100, divided by nasal height, may be either leptorhine when below 480, platyrhine when above 530, or mesorhine when from 480 to 530. The orbital index, *i.e.*, orbital height × 100, divided by orbital width, may be either microseme when below 840, megaseme when above 890, or mesoseme when from 840 to 890. The alveolar index, *i.e.*, the basi-alveolar diameter × 100, divided by the basi-nasal diameter, may be either orthognathous when below 980, prognathous when above 1030, or mesognathous when from 980 to 1030. Similarly the cubic capacity of the cranium may be either microcephalic when below 1350 cubic centimetres, megacephalic when above 1450, or mesocephalic when from 1350 to 1450 centimetres; 1400 being the assumed general average for the human cranium.

By the tabulation of the various measurements certain tangible results have been arrived at, which show that different races of mankind are distinguished from each other by possessing definite characteristics both of face and cranium, so that craniological investigations have a positive value in ethnological research. Some of the most important of these have been summarised by Mr Flower as follows:— The races inhabiting Europe, North Africa, and South-West Asia have a variable or moderate latitudinal index, a low alveolar index, a low nasal index, a moderate orbital index, and a high cerebral capacity; in other words they are mesaticephalic, orthognathous, leptorhine, megaseme, and megacephalic. The Mongoloid races include the extremely brachycephalic[1] Siberian Mongols and Peruvians, and the extremely dolicocephalic Eskimo. They are rarely either truly orthognathous or prognathous, though with a great tendency to the latter, especially in the American branches. The nasal index is usually low, and the Eskimo are the most leptorhine of all known races; the orbital index is usually high, and the cranial capacity very variable. In the Australian, and the dark races with frizzly hair, dolicocephalism prevails almost universally, reaching its extreme in certain Melanesians. These races are equally characterised by prognathism, by the high nasal index (all the true platyrhine races belong to this group), and by moderate or small cranial capacities. As interesting exceptions to this general statement the Andamanese are, it must be noted brachycephalic, mesorhine, and mesognathous, whilst the Bushmen are mesaticephalic and orthognatous.

A valuable addition to the Catalogue consists in a series of tables which have been calculated for finding the principal indices, and which will prove of great service to all who are engaged in similar craniological researches.

[1] By a misprint in the Table, p. 254, the Mongolians of Central Asia and Siberia are said to be dolicocephalic instead of brachycephalic, although the latitudinal index is 880.

STRANGEWAYS' VETERINARY ANATOMY. Second Edition. Revised and Edited by J. VAUGHAN, F.L.S., F.Z.S. Edinburgh, 1879.

THIS edition of Strangeways' *Veterinary Anatomy* is so decided an improvement on the original edition, compiled from the lectures of the late Professor Strangeways, that we think no apology to our readers is needed in introducing it to their notice. Mr Vaughan, himself the teacher of the subject in the New Veterinary College, Edinburgh, has made important changes in the arrangement of the matter, as well as numerous additions, more especially in the sections treating of the structure of the tissues. The style is clear and the mode of description compact and precise. The book is illustrated with six octavo plates and 170 woodcuts.

LIST OF GRANTS IN AID OF SCIENTIFIC INVESTIGATION MADE BY THE BRITISH MEDICAL ASSOCIATION.

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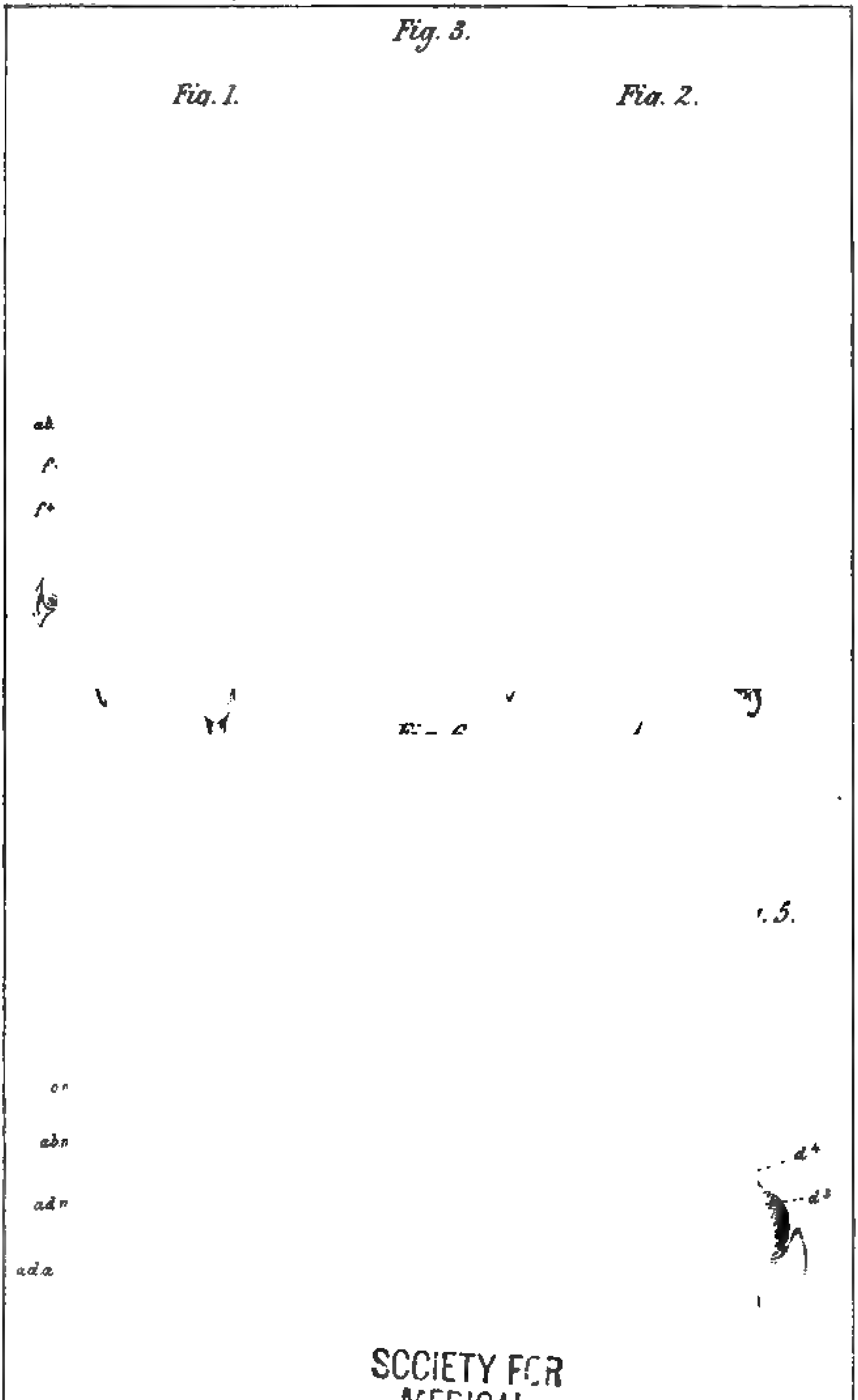

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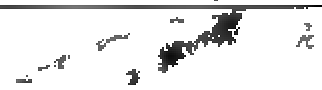


Fig. 2

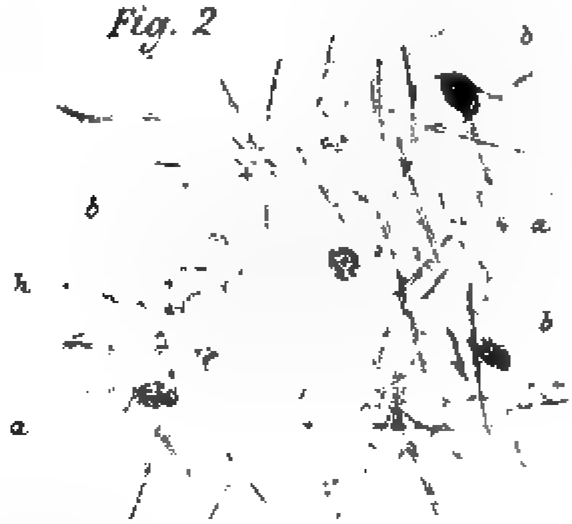
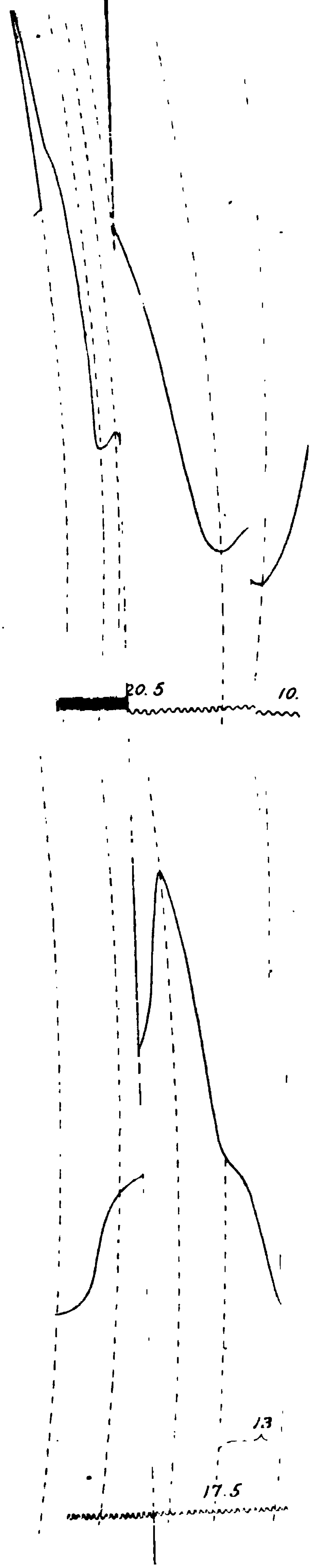


Fig. 4

Fig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Journal of Anatomy and Physiology.

THE STRUCTURE OF THE COMB-LIKE BRANCHIAL APPENDAGES AND OF THE TEETH OF THE BASKING SHARK (*Selache maxima*). By Professor TURNER, M.B., F.R.S. (PLATE XII.)

(Communicated to the Royal Society, Edinburgh, March 1, 1880.)

NATURALISTS have from time to time, for something more than a century, directed attention to the presence on the gills of the Basking Shark of appendages arranged like the teeth of a comb. By various writers they have been regarded as acting like the blades of baleen in the mouth of a whalebone whale, and serving as filters to separate from the currents of water flowing through the mouth of the shark, the small marine organisms on which this fish is believed to live.

Having been engaged some years ago in the study of the structure of whalebone,[1] I was desirous of examining these appendages in this shark, to see if they corresponded in structure with the plates of baleen. It was with great satisfaction, therefore, that I received from the Rev. M. Harvey, of St John's, Newfoundland, during the autumn of last year, along with a number of other interesting objects of natural history, presented by him to the Anatomical Museum of the University, a portion of one of the comb-like fringes, which he had removed from the gills of a Basking Shark captured off the coast of that island.

Before, however, I proceed to describe their structure, it is advisable that I should give some account of the literature of this subject, for although several notices of these fringes have been written in Danish, Italian, and French, and Dr Percival Wright has contributed an article on the subject in *Nature*,

[1] See memoir on the *Balænoptera sibbaldi* in *Trans. Roy. Soc. Edinburgh*, 1870, vol. xxvi. p. 212.

yet a sufficiently continuous narrative of the literature has not yet been drawn up for the benefit of English readers.

The first naturalist to direct attention to these curious structures was Bishop Gunnerus of Trondhjem, in Norway, who described in 1765[1] this shark as living on very small animals, which it retains in the cavity of the mouth by means of whalebone-like fringes attached to its upper jaw. A piece of one of these fringes, examined by Gunnerus, is said by Dr Percival Wright[2] to be now in the Museum at Trondhjem. Shortly afterwards, Pennant, in writing his account of this fish, stated that "within side the mouth, towards the throat, was a very short sort of whalebone."[3] Pennant also directed attention to the small size of the teeth, and thought that the food consisted entirely of sea plants. In 1813 appeared the *Fauna Orcadensis*, by the Rev. G. Low,[4] who described the gills of the Basking Shark as "fringed with a sort of small bristles approaching the nature of whalebone." In an essay "On the Fishes of New York,"[5] Mr S. L. Mitchell says that the Basking Shark is "remarkable for having something within his mouth resembling the horny substance called whale-bone, which has led some persons to call him the bone shark." In 1852 Mr R. Foulis described[6] the capture in the Bay of Fundy of a large shark, probably *S. maxima*, in which each gill opening was provided with a cullender, or comb-like apparatus, apparently for retaining or preventing the smaller portions of food from passing through the gill openings with the water received by the mouth.

In 1869 M. de Brito Capello gave a short description of[7] the comb-like appendages of the Basking Shark, and it is to him that the credit is to be given for having first figured in position on a branchial arch these curious structures. He considered

[1] *Trondj. Selsk. Skrift.* iii. 1765. [2] *Nature*, xiv. 313, Aug. 10, 1876.

[3] *British Zoology*, vol. iii. p. 80, 1769.

[4] This work, although not published until 1813, had been written a number of years previously, as the author died in 1795.

[5] *Trans. Lit. and Phil. Soc. New York*, vol. i. p. 486, 1815.

[6] *Proc. Boston Soc. Natural History*, vol. iv. p. 202, April 7, 1852.

[7] *Journal des Sciences Math. Phys. et Nat. de Lisbonne*, vii. 236, August 1869. In the same *Journal* for 1877, p. 71, M. Barboza du Bocage gives a French translation of Capello's description of these appendages, and refers to the subsequent observation of Steenstrup, Gervais, and Pavesi. See also *Nature*, vol. xvi. May 24, 1877.

that they opposed the entry of foreign bodies suspended in the water into the branchial sac. In 1870 Mr Thomas Cornish gave an account[1] of a shark, supposed to be the Basking Shark, captured at Penzance in that year. He found in front of each gill "a slight elastic apparatus extending the whole length of the ray, 1½ inch deep, which would be precisely represented by a thin small-toothed comb made of whalebone. As the mouth was opened, the little whalebone comb involuntarily fell back to a right angle with the gill ray, and effectually barred the egress through the gills of anything except water which might have been taken into the mouth."

In 1867 Professor Hannover directed[2] attention to a structure, specimens of which existed in the museums of Copenhagen, Christiania, and Kiel, which at first sight he said looked like the young plates of baleen, and had been taken indeed for them. It consisted of a great number of plates of a brown colour, and about 6 inches long, which were united below in a common base of a semi-lunar form. On microscopic examination they were seen to have the same structure as the tegumentary spines of *Raia batis*, *i.e.*, they possessed a central germinal cavity, from which on all sides tubes of dentine ramified. Although nothing was known of the part of the body, or indeed of the animal from which this specimen had been obtained, Hannover, from the resemblance in structure, referred it to an unknown Ray, and perhaps to an extinct species.

In 1873 appeared an important paper by Professor Steenstrup,[3] in which he pointed out that the specimen described by Hannover was undoubtedly the branchial fringe of the Basking Shark, and he quotes Gunnerus and many of the other naturalists to whom I have referred in support of the conclusion he had come to. He regards these fringes as having the function of whalebone, but from the observations of Hannover on their microscopic structure

[1] *Zoologist*, August 1870, p. 2253.

[2] *Dansk. Vid. Selsk. Oversigt*, 1867, p. 46, with a resumé in French. This resumé is reprinted in *Annales des Sciences Naturelles*, Zoologie, ix. 373, 1868. The paper is published *in extenso* in *Kong. Danske Vidensk. Selskabs Skrifter*, p. 485, 1868, with woodcuts of the fringes, and plates showing the microscopic structure.

[3] *Oversigt over det Kongelige Danske Vidensk. Selskabs*, 1873, with a resumé in French.

as being structurally very elongated slender teeth, the presence of which on the gills gives to the genus *Selache* an unique generic character.

In 1874 Professor Pavesi, of Genoa, described[1] a large shark captured in 1870 near Lerici, in the gulf of Spezia, and gave some beautiful figures of the comb-like appendages *in situ*, displaying their relations to the hyoid, the branchial arches and clefts, so that he proved from actual dissection the accuracy of the view advanced by Steenstrup, on bibliographical data, that the specimen described by Hannover belonged to a large species of *Selache*. In a second memoir, published in 1878, he gave an account of[2] another large shark, caught in 1877 in the harbour of Vado, and figured also in it the arches and clefts with the comb-like fringes. Both the Vado and Lerici specimens were examples of *Selache maxima*.

In 1876 MM. Paul and Henri Gervais communicated to the Academy of Sciences[3] some observations on a Basking Shark, captured at Concarneau, Brittany, in which they described the branchial arches with their comb-like appendages. They pointed out that the fringes had not the structure of whalebone, but were of an osseous nature, notwithstanding their flexibility. In chemical composition they consisted of phosphate of lime, mixed with a little carbonate, deposited in the meshes of an organised substance. They also possessed pigment granules, and in them the characteristic dentine tubes were very easily recognised. They gave two figures of the microscopic structure of these fringes, and figured the fringes on the branchiæ. The small size of the teeth is also referred to, and a magnified longitudinal section through a tooth is figured.

In 1876 Dr E. Percival Wright published an article,[4] in which he gave an account of the statements of Gunnerus and Steenstrup relating to the fringes of the Basking Shark, and figured from a

[1] *Annali del Museo Civico di Storia Naturale di Genova*, vol. vi. 1874, plate xi. fig. 1, 3. Also an abstract of this memoir in *Archives des Sciences de la Bibliothèque Universelle*, Dec. 1874. I am indebted to the courtesy of Professor Pavesi for a copy of each of these publications.

[2] *Ibid.* vol. xii. p. 23, 1878, fig. 10.

[3] 29th May 1876, and *Journal de Zoologie*, vol. v. p. 319. Also supplementary note in the same *Journal*, vol. vi. p. 40.

[4] *Nature*, August 10, 1876.

specimen caught at Bofin island, one of the branchial arches with the fringes *in situ*. This article called forth from Professor Allman a letter,[1] in which he said that he had communicated, more than thirty years ago to the Dublin Natural History Society a notice of the capture of a Basking Shark on the south coast of Ireland. An abstract was published at the time in *Saunders's Newsletter*, in which it is stated that the principal object of the communication was to point out the existence "along each of the branchial arches of a very curious and beautiful pectinated structure, consisting of a series of narrow elastic laminæ arranged with great regularity, and constituting along each gill a kind of grating, bearing a close resemblance to the teeth of a comb." Dr Allman pointed out that these laminæ were hard and brittle, and acted as strainers to free the water, before coming in contact with the branchiæ, from extraneous matter. Moreover, from the small size of the teeth, this shark could not be voracious like the allied genera, and must seek its food among the less resisting inhabitants of the ocean. It is to be regretted that this communication of Dr Allman's had appeared originally only in a newspaper, where it was not likely to attract the attention of naturalists.

But though from time to time, for upwards of a century, scattered notices of these curious fringes had appeared in the periodical zoological literature of various countries, systematic writers on fishes have in their treatises ignored the existence of these appendages, notwithstanding their importance in connection with the food and habits of this shark, and their constituting a most important structural peculiarity. Thus they are not referred to in their special memoirs on the Basking Shark by Sir E. Home, Vrolik, and De Blainville, in the special works on fish in which the sharks are described by Müller and Henle, Yarrell, Hamilton in Jardine's *Naturalists' Library*, Parnell, Couch, and Günther; nor in the more general treatises on zoology by Fleming, Jenyns, Thompson in the *Natural History of Ireland* Vander Hoeven, and Carus.

The specimen of the comb-like appendages of the Basking Shark presented to me by the Rev. M. Harvey was 5½ inches long. It consisted of 154 flattened plates, which varied in length

[1] *Nature*, August 31, 1876.

from $4\frac{1}{2}$ to 5 inches. Each plate possessed a semilunar base attached to the mucous membrane of the branchial arch, and this membrane passed for a short distance between the bases of the plates. One horn of the semilune ended in connection with the mucous membrane. The other was prolonged into the slender shaft of the plate, which tapered off to a free point. The breadth of the semilunar base was $\frac{1}{2}$ an inch, but the breadth of the shaft, where it was continuous with the horn, was only $\frac{3}{20}$ths of an inch (fig. 1). The surfaces of the plates were directed towards each other, whilst their thin edges were placed forwards and backwards. The intervals between adjacent plates varied from $\frac{1}{20}$th to $\frac{1}{25}$th inch. The plates were grayish-brown in colour, and with a smooth shining surface, and they were so brittle as to be easily snapped across. The general arrangement of the plates was, indeed, not unlike that of plates of whalebone, and there can be no doubt that they fulfil the office so generally ascribed to them of readily allowing the passage of water through their interstices, and of preventing the passage of small organisms which may be suspended in the water.

When the semilunar base was examined microscopically, it was seen to contain a network of canals, the calibre of which in some cases was equal to, in other cases considerably larger than, the Haversian canals in the compact tissue of the shaft of a long bone. The canals were short, and as it was not unfrequent for several canals to join close together, spaces possessing a width two or three times as great as that of any single canal were formed at their place of junction (fig. 2). The canals lying in the base near its attachment to the mucous membrane opened on the surface, and received prolongations of the mucous membrane.

The anastomosing network of canals was prolonged from the base of the plate into the slender shaft, where the canals terminated in a single elongated cavity, occupying the centre of the shaft, which, diminishing in its calibre in relation to the diminution in the size of the shaft, reached close up to the free point of the shaft, and terminated in a rounded end.

The solid matrix of the plate bounding the anastomosing canals and central cavity had the translucent, somewhat granulated character one sees in the matrix of bone or the dentine of

teeth. This matrix was permeated by multitudes of fine branching tubes. These tubes had the appearance and general mode of arrangement of dentine tubes, but they were nearly twice as large as the tubes of human dentine, and were separated from each other by a larger proportion of matrix. The tubes arose from the walls of the anastomosing and central canals, and were continuous with their cavities. Their course in the matrix was wavy; they branched several times dichotomously, and each tube ended in a number of very fine branches, which anastomosed freely with the corresponding terminal branches of adjoining tubes. Occasionally the larger dichotomous branches anastomosed with those of adjoining tubes. Smaller collateral branches also arose from the sides of the larger tubes. The tubes which were continuous with the central canal of the shaft, and with those anastomosing canals in the base which were nearest to its outer surface, passed almost perpendicularly to this surface towards its exterior, where they ended in the very fine branches already referred to. The anastomosing canals in the base surrounded little islands of matrix, into which the tubes arising from these canals passed, and the tubes from the canals on opposite sides of each island ended in very fine branches about the middle of the island. The tubes which arose from the central canal at the free point of the shaft were smaller than those in and near the base, the amount of matrix between them was greater, and in their course outwards to the surface they were much more curved, and sometimes, indeed, bent almost to a right angle.

In portions of the plates which had been thinned by rubbing on a hone for microscopic examination, it was not uncommon to see tubes divided obliquely or transversely, and when this division occurred where a tube was branching, an appearance resembling somewhat lacunæ of bone, with their branching canaliculi, was produced, but in all the specimens where the tubes could be followed in their entire length no such appearance could be seen. When specimens which had not been rubbed down, but rendered translucent by soaking in turpentine, were examined, the canals were seen to contain a yellowish or brownish yellow material, which looked like a dried and shrivelled membrane, in which red spots and patches, probably

dried blood, could be seen. Moreover, bubbles of air were present in the canals (fig. 4). This membrane was, without doubt, derived from, and was continuous with, the vascular mucous membrane at the base of attachment, which was prolonged into the canals, so that the canals undoubtedly contain blood-vessels.

Hannover, in his account of the structure of the plates, speaks of pigment as occurring in them. I have also observed yellowish or brownish yellow particles in the canals, but it may be a question if these were anything more than portions of their membranous contents, broken up into small irregular pieces when the plate was rubbed thin for microscopic purposes.

From the above account of the structure of these plates there can be no doubt that their type of structure resembled the dentine of a tooth. The whole periphery of the plate consisted of a hard unvascular dentine, the tubes in which were very characteristic. In a considerable part of the shaft these tubes arose from a single central cavity which corresponded with the pulp-cavity, and undoubtedly contained a vascular pulp. But in the semilunar base the single central cavity did not exist, but was replaced by a set of anastomosing canals, which collectively represented a pulp-cavity, and which, without doubt, had contained a vascular pulp. These canals were separated from each other by a matrix containing characteristic dentine tubes. Although I have no observations to offer on the development of these plates, there can, I think, be no doubt, from their resemblance in structure to the dentine of a tooth, that they have arisen, like it, from a conversion of the odontoblast cells of a vascular pulp into a hard calcified dentine substance. In all probability, therefore, they arise from papillæ formed in the dermal or subepithelial layers of the mucous membrane covering the branchial arch, and the formation of papillæ is doubtless preceded by the involution of the surface epithelium, and the production of an enamel organ, which, as Mr C. S. Tomes has shown, is formed in the development of the teeth of fish, whether or not enamel be subsequently developed.[1]

This view is strengthened by what has been seen of the development of the spines on the skin of the sharks. As is well known the dermal spines of these fish correspond, generally, in

[1] *Philosoph. Trans.* 1875, p. 257.

their structure with their teeth, and dentine enters very materially into their formation. The observations of Hertwig have shown[1] that prior to the formation of these spines a papilliform elevation of the dermis takes place, and that this papilla is covered by epidermis, the rete Malpighii of which covering forms the enamel organ. Calcification of the papilla then takes place, and the production of dentine from its cellular constituents.

In their structure, therefore, these plates differ in a marked manner from those of whalebone. Although canals, containing vascular papillæ, traverse the baleen in the long axis of the plates, yet these do not anastomose with each other. Again, in the formation of dentine the solid matrix is due to a calcification of the odontoblast cells of the papilla, so that it is a dermal or sub-epithelial structure, and is thus derived from the mesoblast. The solid matrix of whalebone, on the other hand, is produced by a cornification of the epithelial coverings of the various groups of papillæ that I have described in my account of the structure of whalebone already referred to. Hence, the cornified whalebone blade is an epithelial and not a sub-epithelial structure, and it takes its rise from the cells of the epiblast. It corresponds, therefore, in its morphological position, not with the dentine of a tooth, but with its enamel.

As all the naturalists who have studied these comb-like branchial appendages in the Basking Shark agree in ascribing to them a similar office to that discharged by the baleen plates in the mouth of a whale, they provide us with an excellent example of objects which, though different in structure and mode of origin, yet fulfil corresponding physiological properties.

But the Basking Shark is not the only Elasmobranch in which a filtering apparatus is developed in relation to the branchial arches and clefts. Dr Andrew Smith, in his account of the fishes of South Africa,[2] describes a shark under the name of *Rhinodon typicus*, which has—

"The inner extremity of each branchial canal obstructed by a sieve-like apparatus, consisting of a congeries of cartilaginous tubes closely set together, directed laterally, and the inner extremity of each fringed with a delicate membrane offering an obstruction to the passage of anything but fluid."

[1] *Jenaische Zeitschrift*, 1874.

[2] *Illustrations of the Zoology of South Africa*, London, 1849.

The teeth in this shark were small, and Dr Smith surmises that it feeds on small molluscs, &c., which it receives into its mouth along with the sea-water. Whilst the water is expelled by muscular action through the gill-clefts, the small animals are intercepted by the fringe of delicate membrane. It is not likely that the sieve-like apparatus in *Rhinodon* has the same structure as the comb of *Selache;* for although Dr Smith does not enter into its microscopic structure, yet, from the expressions "cartilaginous tubes" and "delicate membrane," it consists presumably of a much less hard and rigid material than the comb-like plates of *Selache.*

But appendages similar to those of *Selache* have not been confined to existing species of sharks, for Professor van Beneden obtained from the Antwerp Crag comb-like structures, the exact signification of which was at first difficult to determine. When Hannover published his account of the specimen in the Copenhagen Museum, Van Beneden at once recognised the resemblance between it and the specimens from the Antwerp Crag, and described them as belonging to an extinct Elasmobranch, which he named *Hannovera aurata.*[1] After Steenstrup had, however, shown the identity of the Copenhagen specimen with the branchial appendages of the Basking Shark, Van Beneden has substituted the name of *Selache aurata* for that which he had originally employed.[2]

Along with the comb-like branchial appendages, Mr Harvey also sent me a portion of the dentary border of the jaw with the teeth *in situ.* The teeth were arranged in seven rows, and were imbedded at the base in the mucous membrane. Each tooth was not more than $\frac{3}{10}$ths of an inch long, and a little less than $\frac{2}{10}$ths of an inch wide at its base. They were conoid in shape, with sharp-pointed free ends, somewhat flattened on the anterior and posterior surfaces, and without serrations (fig. 5).

When longitudinally bisected and examined microscopically no central pulp-cavity was seen, but the base and the body of the tooth were traversed by a number of canals. One larger than the rest passed up the centre of the tooth towards its apex, and from it arose a number of collateral canals, which anastomosed

[1] *Bulletin de l'Acad. Roy. de Belgique,* xxxi. 504, 1871.
[2] *Ibid.* xlii. 294, 1876.

and formed a network of canals situated between the central canal and the periphery of the tooth. The central canal had at the base of the tooth a transverse diameter about three times that of a Haversian canal in a human bone, but diminished in calibre as it passed towards the apex of the tooth. The arrangement of the canals corresponded generally to what I have described in the basal part of the plates of the comb-like fringes, but the islands of matrix between the canals were somewhat larger than in the plates of the comb. These islands were traversed by waving, branched, dentine tubes, which, arising from the walls of the canals, converged from opposite sides to the centre of an island, where they ended in numerous fine branches. These canals had contained, I have no doubt, prolongations of the vascular mucous membrane of the gum. The dentine tubes closely resembled in appearance and arrangement those in the islands of matrix in the base of the plates of the comb (fig. 6).

On the free surface of the tooth was a dense, opaque white layer, which consisted of pure dentine, without any admixture of vascular canals. In this layer the tubes were more compactly arranged than in the subjacent core; and as they passed in a wavy branched course, almost perpendicularly to the free surface of the tooth, they were not so curved as the tubes of the core. This layer was better defined on the anterior than on the posterior surface of the tooth, the former of which had the opaque white appearance more distinct than the latter.

In its structure the tooth, like the semilunar base of the plates of the comb, consisted of a hard unvascular dentine externally, and of a central core in which were numerous anastomosing canals surrounded by a matrix containing characteristic dentine tubes. These canals collectively represented the pulp-cavity. The chief difference between the plate and the tooth was this, that in the plate the canals formed ultimately in its shaft only a single central cavity, whilst in the tooth the anastomosing arrangement of the canals was preserved up to the apex of the core, and no single pulp-cavity existed.

The question, therefore, may now be considered as to the name which should be applied to the tissue which forms the semilunar base of the plate and the central core of the tooth. Mr

C. S. Tomes, in his recent memoir "On the Structure and Development of Vascular Dentine,"[1] proposes to distinguish four varieties of dentine, viz., hard unvascular dentine, vaso-dentine, plici-dentine (where the tissue has been complicated by foldings of its surface, as in the tooth of *Labyrinthodon*), and osteo-dentine. This tissue is obviously neither the hard unvascular dentine, though that is found on the surface of both the plate and the tooth, nor plici-dentine. Mr Tomes defines vaso-dentine to be a tissue, without true dentinal tubes, formed from the odonto-blast layer of the pulp, and permeated by canals closely filled by capillary blood-vessels, and gives as an example the tooth of the Hake (*Merluccius vulgaris*), in which fish the pulp-cavity is bounded by a wall of this substance. The osteo-dentine he defines as a tissue devoid of true dentine tubes, derived from a calcification of the formative pulp, and not from a specialised odonto-blast layer. It contains numerous canals, which do not,

> "Except as a matter of accident, contain capillary blood-vessels, that is to say, the dentine as it is formed is not deposited round capillaries so as to enclose them within itself, and hence very few of the channels do contain capillaries; when they do the capillary only forms a part and not the whole contents of the tube" (canal).

He gives as an example the tooth of the Pike.

It is obvious that the core of the tooth, and that of the semi-lunar base of the plate of the comb, of the *Selache maxima*, do not correspond with either the vaso-dentine or the osteo-dentine according to these definitions, for though, in both, canals occur, which presumably contain capillary blood-vessels, yet the matrix in both is permeated by numerous branching dentine tubes, and there can, I think, be little doubt, from the presence of these tubes, that the matrix surrounding them has been formed by calcification of the odonto-blast cells of a dentine germ papilla. In its mode of origin, therefore, this matrix would correspond with the matrix of Mr Tomes's vaso-dentine, but would differ from it in being, not a tubeless matrix, but being permeated by numerous dentine tubes.

Hence, it seems to me that Mr Tomes has given too limited a definition to the term vaso-dentine, in excluding from it den-

[1] *Philosophical Transactions*, part 1, 1878.

tinal tissue penetrated by vascular canals, the matrix of which tissue is permeated by dentine tubes; for the presence of these tubes is the most reliable structural evidence that the material under examination is a form of dentine. The original definition of Professor Owen,[1] that vaso-dentine consists of a dentinal tissue into which vascular medullary canals are prolonged, seems to me to be more appropriate, because it would include dentinal tissue, in which both tubes and vascular canals existed; and, accepting this definition, the core of the teeth and the interior of the semilunar base of the comb-like plates of *Selache maxima* are to be regarded as formed of a vaso-dentine, covered on the exterior by a hard unvascular dentine.

The presence of bodies possessing the structure of teeth on the gills of the Basking Shark is not so aberrant an arrangement as might at first sight appear. It is well known that a row of teeth is situated on each branchial arch in many of the osseous fish, so that there is a tendency amongst fish for dental structures to arise in connection with the mucous membrane covering this part of the skeleton. The peculiarity in the Basking Shark, therefore, is the excessive development which the branchial teeth undergo, a development which is correlated with the small size and simple form of the maxillary and mandibular teeth, with the non-predaceous habits of the fish, and with the particular nature of the food on which it lives.

Addendum.—When this paper was communicated to the Royal Society, Professor Duns, D.D., of the New College, told me that in the Museum of that college was a specimen of a comb-like structure similar to what I had described, but that no record had been made either of the donor of the specimen, or of the locality whence it had been obtained. Professor Duns has kindly allowed me to examine the specimen, which is an excellent example of the branchial comb of the Basking Shark. It is apparently from a somewhat younger and smaller specimen, as the plates are not quite so long as those described in this paper.

[1] *Odontography*, p. xvii.

Explanation of Plate XII.

(I am indebted to my friend, Professor J. H. Scott, M.D., for the drawings in illustration of this paper.)

Fig. 1. Surface of one of the plates of the comb-like appendage —natural size.

Fig. 2. Magnified longitudinal section through a portion of the semilunar base, showing the vaso-dentine formed of anastomosing canals and dentine tubes proceeding from them into the matrix.

Fig. 3. Magnified longitudinal section through the shaft of a plate, showing the central canal with the tubes of the hard unvascular dentine.

Fig. 4. The tip of one of the plates rendered translucent by turpentine, and not by section or grinding. The rounded end of the central canal is shown, occupied by the dried vascular membrane, also an air-bubble at the end of the canal. Hard unvascular dentine forms the boundary of the canal. (Magnified).

Fig. 5. Antero-posterior section through the jaw of *Selache maxima*, showing the teeth *in situ*—natural size.

Fig. 6. Magnified longitudinal section through a tooth, showing the cap of hard unvascular dentine and the core of vaso-dentine.

NOTE ON THE GANGLION-CELLS OF THE ELEPHANT'S RETINA. By George Thin, M.D.

In a footnote to a paper on "The Optic Nerve-Fibres and Ganglion-Cells of the Mammalian Retina," published in vol. xiii. p. 141, of this *Journal*, I suggested that the method therein described of preserving the retinal nerve elements for examination might be utilised for the preservation of eyes from animals which are difficult to procure in this country.

I am indebted to Mr R. F. Frost, M.R.C.V.S., Royal Artillery, Burmah, for having, in response to an invitation published in the *Veterinary Journal*, sent to the editor of that serial two elephant's eyes, which were prepared in accordance with the directions given in the paper referred to. They were kindly handed to me by Mr Fleming.

On examining the retina of one of the eyes in glycerine, I found that the ganglion-cells could be isolated in considerable numbers. Compared with the cells of the retina of the sheep and cat, on which my previous observations had been made, I found amongst those which I isolated a much greater uniformity of size. The cell-processes were not so well preserved as in those which I had prepared from these animals, some of the cells having lost all traces of them. In some, however, small portions of two large broad processes, extending from opposite poles of the cell, were still adherent.

As the elephant's retina is probably not very frequently examined, the following measurements of four cells, representing very nearly all the sizes I observed, may be of interest:—

		mm.
Cell 1.	Cell measured, ...	·024 × ·027
,,	Its nucleus measured, . . .	·009 × ·006
Cell 2.	Cell measured, ...	·036 × ·024
,,	Its nucleus measured, . . .	·012 × ·012
Cell 3.	Cell measured, ...	·030 × ·027
,,	Its nucleus measured, . . .	·009 × ·009
Cell 4.	Cell measured, ...	·030 × ·033
,,	Its nucleus measured, . . .	·012 × ·011

I observed none larger than the largest, and none smaller than the smallest of these measurements.

NOTE ON THE STRUCTURE OF THE STYLE IN THE TONGUE OF THE DOG.

By JOHN H. SCOTT, M.D., *Professor of Anatomy, Otago University.*

THIS so-called "worm" is, as is well known, a cartilaginous rod lying in the mesial plane usually in the under part of the tongue. Its structure has not, I believe, been described, but presents one or two interesting features.

It is composed of cartilage—almost entirely cellular in character. The cells are closely packed together, and are consequently mostly polygonal in form. The intercellular substance is very limited in amount, and, throughout the greater part of the cartilage, merely serves to separate the cells. Occasional larger patches are observed, and in these delicate fibres may be seen forming interlacing bundles and passing in between the adjacent cells. The style is invested by a thick fibrous perichondrium with which these fibres of the matrix are continuous. This rod of cartilage is distinctly vascular. A somewhat wide-meshed network of capillaries is to be seen throughout its substance in injected specimens. The vascularity is more marked towards the ends than near the centre of the rod. These capillaries are continuous with those of the perichondrium, but an artery and vein of some size are also usually to be seen transversely divided in transverse sections.

My attention was first directed to this matter by Mr A. B. Stirling of the Edinburgh Anatomical Museum, when I was writing, in 1877, my thesis "On the Anatomy of the Dog," on the occasion of my graduation as M.D., and a short description of it was incorporated in that thesis. It is from preparations made by him that I have satisfied myself of the vascularity of the structure. He informs me that it was the custom in Stirlingshire in his youth to extract this "worm" as a preventive to rabies.

NOTE ON THE ANATOMY OF THE INDIAN ELEPHANT.

By ALFRED H. YOUNG, M.B., *late Assistant Lecturer on Anatomy, The Owens College, Manchester.*

THE recent contributions to our knowledge of the anatomy of the Indian Elephant by Professor Miall and Mr Greenwood[1] (jointly) contained a comprehensive and almost complete account of the muscular arrangements of the species. In their concluding remarks, however, these observers "direct the attention of future dissectors to certain points which have been passed over or inadequately treated"; among such they indicate the sterno-humeral and superficial cervical muscles (*pectoralis, masto-humeralis, sterno-maxillaris, sterno-mastoideus*), which, because of their mutilation prior to dissection, were insufficiently noted, whilst such results as were obtainable from an interpretation of the remaining shreds of muscle were not deemed altogether trustworthy. Miall and Greenwood requested, therefore, that the first opportunity of correcting their observations on these points might be seized; to this end the following brief notes are intended.

Miall and Greenwood describe accurately the *pectoralis major* as being separated into superficial and deep portions; but in my specimen the latter possesses a somewhat more extensive origin, inasmuch as some fibres spring from the abdominal aponeurosis. They were not able, however, to distinguish the *pectoralis minor* of Cuvier and Laurillard.[2] This muscle does exist. It arises by a pointed origin from the first rib close to its junction with the sternum, and, widening as it passes outwards, forms a triangular muscle, which is inserted by its base into the fascia covering the supra-spinatus. It has no attachment to the humerus.

Masto-humeralis.—The description given by Miall and Greenwood of this muscle is correct. It takes origin by two distinct heads, of which the larger springs from the basi-occiput and the

[1] *Jour. of Anat. and Phys.* 1878, vol. xii. pp. 261–385; vol. xiii. p. 17.

[2] *Recueil de Planches de Myologie*, pl. 292–3, *f.* 3, which apparently corresponds to *f.* 2 of the index.

smaller from the mastoid process; the two heads soon unite to form a strong muscular bundle, which is inserted into the humerus just below its tuberosity.

The *sterno-maxillaris* arises from the first piece of the sternum just in front of the sternal crest, and slightly from the first rib. The fibres run forward in contact with those of the corresponding muscle of the opposite side, and, near the lower jaw, form a flattened expansion, they then diverge from the middle line upon either side, and are inserted into the inferior border of the mandible in front of the digastric.

Sterno-mastoideus.—Miall and Greenwood state that "a muscle which may be held to correspond with this, though it has no attachment either to the sternum or the mastoid, springs from the first rib several inches above the sterno-maxillaris (*i.e.*, nearer the vertebral column). It passes obliquely forwards and outwards, contracting to a tendon which finally expands upon the root of the zygoma." In my specimen this muscle, which might, perhaps, be more appropriately termed a sterno-zygomaticus, corresponds more closely to that figured by Cuvier and Laurillard (pl. 274–5, *b*; 292–3, *b*). It arises, close to its fellow of the opposite side, from the anterior border of the great median sternal crest, and is inserted into the zygoma opposite the condyle of the lower jaw. Before its insertion the muscle is flattened and crosses the parotid gland.

Thes *terno-thyroideus*, which in Mialls' and Greenwood's specimen took origin exclusively from the first rib, I found, in addition, arising from the anterior border of the sternum.

Mayer and Watson had previously described the *digastricus* as being divided into anterior and posterior bellies, respectively, by means of a tendinous intersection. Such is the case also in my specimen. Miall and Greenwood were not able to distinguish this characteristic in the digastric of their elephant.

There is no separate *stylo-hyoid.*

The *coraco-brachialis* possesses a more extensive insertion than Miall and Greenwood describe. The upper fibres, slightly separated from the rest, are inserted into the humerus *above* the insertion of the latissimus dorsi, they reach up as far as the capsule of the shoulder joint; the remaining and greater part of the fibres are inserted into the shaft of the humerus extending

from the insertion of the latissimus dorsi as far down as the internal condyle.

In the Indian Elephant there is, consequently, a coraco-brachialis representing the long, short, and middle varieties of Wood.[1]

I have, in conclusion, to acknowledge the kindness of Mr Wall, M.R.C.V.S., Warrington, to whom I am indebted for the opportunity of examining a fine young elephant shortly after its death.

[1] "On Human Muscular Variations and their relation to Comparative Anatomy," *Journ. of Anat and Phys.* 1867, vol. i. p. 45.

ILLUSTRATIONS OF THE PATHOLOGY OF SARCOMA, FROM CASES OF SUBCUTANEOUS CYSTIC TUMOURS.

By CHARLES CREIGHTON, M.D., *Demonstrator of Anatomy, Cambridge University.* (PLATES XIII.-XV.)

THE observations recorded in this paper, to illustrate the general pathology of sarcomatous growths, are taken from cases that would not all be admitted as unexceptionable instances of sarcoma. The cases are:—(1) a sero-sanguineous cyst of the neck of a dog; (2) a mucous sarcoma of the neck of a dog with a cystic interior, and a fluctuating tumour from the subcutaneous tissue of the hip of a dog, of precisely the same structure; (3) a cystic tumour, with granulation-like interior, from between the scapulæ in a man; and (4) a spindle-celled sarcoma from the head of a dog, with its centre excavated into a cystic cavity crossed by a close network of trabeculæ. All but the first case might perhaps be admitted as varieties of sarcoma; the pair of growths under (2) being *Sarcoma myxomatodes*, the third case a granulation-like or round-celled sarcoma, and the fourth a spindle-celled sarcoma. But it is precisely the first case, the sero-sanguineous cyst, that is most full of instruction for the pathology of all the others; and although it was a cystic tumour with only a thin fringe of solid structure round its walls or extending into the tissue subjacent, I reckon it as presenting a better physiological type of sarcomatous formation than specimens more typical in structure would have done. The grouping of those five cases will appear less arbitrary than it may seem at first sight, if it be kept in mind that they all grew from connective-tissue cells, that they were all subcutaneous in position, that four of them were excavated into cysts, and the fifth of so fluctuating a texture as to have been diagnosed as a cyst; and that three of them occurred in the neck region. To illustrate the structure of sarcoma, to go over again the well-trodden ground of varieties of connective-tissue tumour formation, a group of cases might easily have been put together, which were under no suspicion of failing in the generic characters of sarcomatous growths. But, to advance beyond the familiar knowledge

of histological structure, and to obtain an insight into the forces at work in the production of connective-tissue tumours, one must resort to the bye-ways of tumour pathology, and seize upon those cases divergent from the classification type, which are instructive in proportion to the degree of their divergence. The five cases to be described in the sequel seem to me to afford, both individually, and as a mutually explaining series, an amount of instruction for the pathology of sarcoma which a study of more perfect examples of sarcoma-structure would have failed to give.

Having thus recognised, and endeavoured to meet, the objection to an apparently incongruous grouping of cases, and an apparent disregard of the ordinary classification of tumours, I shall proceed to treat of each case by itself, and with reference to its nearest neighbours, and afterwards to sum up the conclusions for the general pathology of connective-tissue growths which the whole series supplies.

I. Pathology of a Sero-Sanguineous Cyst from the Neck of a Dog: Mode of Origin of Red Blood-Corpuscles. (Plate XIII. and figs. 4 and 5, Plate XIV.)

Description of Cyst and Contents.—The tumour was removed from the neck of a retriever dog at the Brown Institution, London, in July 1875.[1] The cystic interior contained a considerable quantity of clear brownish fluid, which I examined with the microscope immediately after the operation. The note made at the time states that the fluid contained a large number of red blood-corpuscles, some colourless corpuscles, and some large cells filled with yellow granules. (This tumour, as well as the others described in the sequel, was preserved for microscopic examination in the following way:—It was placed for a week or ten days in a 2 per cent. solution of potassium bichromate; afterwards in an equal mixture of spirit and water, which was changed once or oftener as it became turbid; and ultimately in pure methylated spirit.) The cystic cavity had an average

[1] I am indebted to Dr T. K. Chambers, the owner of the dog, for the information that there has been no recurrence of the disease. Dr Chambers has also been so good as to inquire into the alleged occurrence of the same kind of formation in the neck in other dogs of the same family, but he is not satisfied that the keeper had distinguished between abscesses and cysts.

diameter of about 2 inches; the interior was in part smooth and somewhat folded, in other parts it had a more ragged appearance, being covered with fine trabeculæ or frayed out into festoon-like pieces of tissue. The cyst had no distinct outer capsule; it was removed along with a considerable piece of one of the neck muscles with which it was intimately connected, and its periphery was otherwise formed of dense or indurated connective tissue. A cluster of very large lymphatic glands adhered to its under surface; their condition proved to be of the greatest interest, and will be referred to afterwards.

Minute Structure of the Cyst Wall.—The structure that covered the interior of the cyst was in part membrane-like and little more than a line in thickness; at other parts, where the surface was more irregular, there was as much as a quarter of an inch of tumour substance, and, as I shall afterwards mention, the new formation penetrated for a considerable distance among the bundles of the subjacent muscle. The largest sections of tumour substance were obtained from a prominent ridge which had an artery the size of a crow-quill for its central stem; the surface of this ridge was ragged or villous, and the more central parts uniform and dense. The structure of the irregular surface and that of the uniform and firm substratum will fall to be noticed separately, and I shall begin with the latter, as being the initial condition of the new growth.

The most characteristic structure in the deeper parts of the cyst wall is that which is drawn in fig. 1. The central objects in the figure are a wide vessel of capillary structure and its two cross branches. The larger vessel is completely surrounded by cells to the depth of several rows; cells of the same kind occur also more sparsely in the connective-tissue ground-substance through which the vessels run. The cells have a nucleus and a broad zone of cell-substance; their size may be estimated from the fact that the nucleus alone is as large as a colourless blood-corpuscle. In shape they are cubical or polyhedric, one side being generally rounded. Their protoplasm or cell-substance is clear or watery, and tinted with the colour of hæmoglobin; the nucleus, as is usual, becomes stained with the colouring reagent (logwood).

Perivascular groups of cells, as in fig. 1, with wide intervals

of fibrillar ground-substance, are very commonly found in the deeper parts of the cyst wall, and the appearance is too characteristic of the growth not to be specially noted. But, in other preparations, and nearer the surface, the cells are thickly scattered throughout the connective-tissue ground-substance, and in less obvious relation to the walls of vessels, and it is in the latter situations that their origin is best seen. Fig. 2 shows the mode of origin of the characteristic cells. The almost homogeneous ground-substance is beset with large spindle-shaped cells, and these transform themselves into the more spherical or cubical kind of elements above described, the protoplasm of the cells assuming at the same time the peculiar hæmoglobin tint. Several examples of the cells more highly magnified are given in the upper half of Plate XIV., the reddish tint of their clear or watery protoplasm being represented in colour approximately.

These cells are *hæmatoblasts*, cells from which red blood-corpuscles are derived. The name of hæmatoblast has been introduced to notice, if not invented, by M. Hayem in a series of papers in the latest numbers of the *Archives de Physiologie;* it is there used to denote a certain class of elements said to exist in the blood as it circulates in the blood-vessels, which are not red blood-corpuscles but the antecedent stage of them. My observations relate to an entirely different point, but the name used by M. Hayem is obviously the appropriate name for all cells whatever from which red blood-discs may spring. The hæmatoblasts of which I here speak are derived from the connective-tissue cells. A certain tract of connective tissue presents its embryonic features, the cells being of great size or plumpness, spindle-shaped, with more or less obvious long processes. The embryonic connective-tissue cell changes into a hæmatoblast by becoming cubical or spherical, and by acquiring a clearer or more watery and at the same time hæmoglobin-tinted protoplasm. This transformation takes place in the connective-tissue cells lying in their natural positions in the ground-substance, and more particularly round the walls of vessels.

Mode of Origin of the Cystic Cavity.—Such a growth and transformation of embryonic connective-tissue cells as I have described in the last paragraph, would, if it went no further,

lead to the formation of a solid tumour of a size corresponding to the area over which the cell formation and cell change extended. A spindle-celled sarcoma, or a round-celled sarcoma, or, still more pertinently, as I shall show in the next section, a mucous sarcoma, would have sprung up in the embryonic connective tissue in precisely that way. But the result in this case is a cyst, and we have to account for the central softening of an originally solid connective-tissue formation which had the structure that may still be seen in the deeper parts of the cyst-wall. The central softening is due to the *instability of the hæmatoblasts*, and that instability is neither more nor less than their natural tendency or destiny to produce red blood-corpuscles from their substance.

As the initial stages of the new formation are still to be seen in the substratum of the cyst-wall, so the process of cyst-production may be seen at work on its free surface. The interior, as I have already stated, was in many places ragged or villous; the microscopic appearance is shown in fig. 3. Parallel vessels run up to the surface and appear as if to end there. Each vessel is the centre of a tract of cells, of the kind spoken of as hæmatoblasts, and those of the cells that are more immediately perivascular retain the complete form of such cells. But the hæmatoblasts more remote from the vessel wall are undergoing the process of breaking up, whereby red blood-corpuscles are produced. It is not difficult to understand how this process of breaking up in individual cells so grouped should lead to the disintegration of a solid core or to the formation of a cavity in the centre of the hyperplastic area. The melting of the solid tissue takes place in the intervals between the vessels and their immediate investment of cells, and it extends towards the deeper parts of the new formation following the same intervascular tracts. The surface of the cystic cavity has, therefore, always a somewhat villous character, owing to the free projection, for a certain distance, of the central vascular stems; and the melting away of the solid walls takes place at the rounded ends of the villous projections and in the clefts between them. The solid wall thus constantly worn away is recruited from the new formation in the deeper layers; there is probably a limit to the continued supply of new zones of cells, but the tumour process

had at least extended among the bundles of the subjacent muscle, and appeared to be spreading into the surrounding tissues in the so-called manner of "infiltration." In those deeper and newer regions of invasion, the embryonic cells had very obviously the perivascular grouping; the individual cells were younger or more immature, being more nuclear and with a smaller zone of protoplasm.

The disruption of the solid core of new growth may be compared to the formation of an abscess-cavity in an indurated inflammatory area, The description of abscess-softening given by Stricker[1] may be set beside the account of cystic softening given above. It is in both cases the unstable character of the new cellular product that leads to the liquefaction or melting of the hard nodule, the fluid being in the one case pus and in the other case blood. The instability of the connective-tissue cell in inflammation may or may not have its physiological type in the instability of the hæmatoblast, but the instability of the hæmatoblast is itself rendered intelligible by observing what results from it. The large spherical or cubical cells, with a wide zone of hæmoglobin-tinted protoplasm, do not rest at that stage, but they advance to fulfil what may be called their destiny. The hæmoglobin-tinted protoplasm is disengaged from the cells in the form of buds, and the buds take the form of ordinary red blood-discs. The breaking up or budding of their protoplasm is accompanied by remarkable division of their nuclei; after the round pieces of protoplasm have been disengaged, more or less of the original nucleus remains, cleft into three or four or more small round fragments, and surrounded by a narrow fringe of the reddish-yellow cell-substance; and those remains of the original hæmatoblasts are not unlike the well-known forms of pus-cells with the trefoil kind of nucleus. I shall now describe minutely the mode of origin of red blood-corpuscles from the hæmatoblasts.

Mode of Origin of Red Blood-Corpuscles from Hæmatoblasts (Plate XIV.).—The upper part of Plate XIV. shows a large collection of hæmatoblasts, a few of them entire, and the greater number in the act of breaking up; they are drawn accurately (though the scale is not quite uniform throughout), and they

[1] *Vorlesungen über Allgemeine und Experimentelle Pathologie*, p. 275.

represent only a few of the almost innumerable varieties of the breaking-up process. The entire and perfect hæmatoblast (as drawn in one of the lower rows of the group) is a large cubical or irregular-sided element, having a nucleus which stains well, and a broad zone of clear or watery protoplasm which retains the reddish-yellow tint of hæmoglobin. The red blood-discs are simply detached portions of this zone of tinted protoplasm; no part of the logwood-stained nucleus enters into their formation. But the nucleus does not remain unaffected in the breaking up of the hæmatoblast into blood-discs. Indeed the phenomenon that first arrests the attention is the division or cleavage of the nucleus into several fragments, which may be of unequal size. In nearly all the examples drawn in the plate, this extensive fission of the nucleus is clearly shown. The small round logwood-coloured particles are often connected with one another by threads of the nuclear substance (also stained), and that may be taken as good evidence that they are the disjoined fragments of an originally single body. The disruption of the nucleus is evidently an event connected with the detachment of pieces of the outer or protoplasmic zone to become red blood-corpuscles. There is probably not an exact correspondence between the number of pieces into which a nucleus divides, and the number of blood-discs formed by detachment from the protoplasm of one cell. But if there is no exact correspondence in the number of fragments, there can be no question that the fission of the protoplasmic zone and the fission of the central or nuclear zone proceed hand in hand. One of the most significant facts in this remarkable process is that a detached portion of the cell-substance is often followed, as it were, by one of the rounded fragment of the nucleus. The round logwood-coloured nuclear particle has no permanent share in the structure of the red blood-corpuscle, but it often seems to go off with the reddish protoplasmic bud, as the latter frees itself from the parent hæmatoblast.

A careful study of the hæmatoblasts in process of breaking up shows that the mode of origin of the red blood-discs is on the whole uniform. The most certain evidence of the stages of this process would be obtained, naturally, by watching a particular hæmatoblast through the whole series of changes. In such material as

I have here to deal with, that method could not be applied; but the stages of the process may be inferred with hardly less certainty from putting together the various appearances of the hæmatoblasts as they were fixed when the elements ceased to live. The varieties of form in the disintegrating hæmatoblasts are almost innumerable, each one differing in some small particular from all the others; and from so great an abundance of coexisting forms, standing for stages, or degrees, it is not difficult to construct the succession of events with an accuracy that is practically sufficient. One of the most common appearances is that of a hæmatoblast with its nucleus broken up into several round fragments, the fragments dispersed more or less widely in one or more directions, but still hanging together, and the cell-substance following, or rather preceding the directions of the nuclear particles.

If the hæmatoblast be supposed to possess the power of amœboid movements, this condition might have resulted from the uniform circuit of the protoplasm yielding, and portions of the protoplasm flowing out like pseudopodia. The fission of the nucleus, and the movements of its particles, are associated with those of the protoplasm, and a not uncommon appearance is that of a small round nuclear particle adhering like a knob to the narrow end or on one side of the pear-shaped or spherical portion of hæmoglobin-tinted protoplasm. In some instances, such, for example, as are drawn at the right lower corner of the group, the fragments of the nucleus do not disperse, and the blood-discs appear to fall out, as it were, from the uniform and unbroken contour of the cell. That particular appearance is more than one of juxtaposition of blood-discs to a nucleus; by adjusting the focus, it can be seen that the blood-disc is not yet independent of the rest of the protoplasm. The earliest change in the entire hæmatoblast is, no doubt, the cleavage of the nucleus into two or more pieces, as shown in several cells in the plate. It is often observed that the undivided nucleus lies at one side of the cell, leaving the greater part of the cell-substance as if aggregated clear of the nucleus. Sometimes there may be seen a blood-disc as if lying within the contour of an entire hæmatoblast, or upon the face of it; but anything like an intracellular origin of blood-corpuscles is so much rarer than the

mode or origin by budding, or by detachment round about the cell, that it may be practically left out of account.

The detached pieces of hæmoglobin-tinted protoplasm are often at first pear-shaped or otherwise elongated, and the circular pieces are not at first flattened but spherical. The perfect discoid shape, with raised centre, is not wanting in the blood-discs that are abundantly scattered among the hæmatoblasts, but those characters would seem to be acquired after the pieces of protoplasm become free.

It is not conceivable that any of the appearances above described are due to the action of reagents or the cells. The mode of preparation that was followed is well adapted for fixing the elements of the tissues in their natural condition, and any suggestion of artificially-produced appearances may be at once set aside. What has been described as the hæmoglobin colour in the hæmatoblasts is precisely the same as the colour of the red blood-corpuscles which they give origin to; otherwise that colour might have seemed to be due to the use of chromium compounds in preparing the tissue.

The fate of the broken-up nucleus, after the protoplasm has been detached in the form of red blood-corpuscles, is not altogether clear; but it may be conjectured. It is a somewhat remarkable fact, that although single particles of the nucleus are often seen to follow and to adhere to the blood-discs as the latter break off from the parent cell, yet the number of such loose single particles that may be found in a region where blood-formation has been active is by no means great. It is conceivable that the more or less scattered nuclear fragments gather themselves together after the protoplasm has budded off; and it is a matter of observation that the greater number of the fragments into which a nucleus divides do remain in close contact. These aggregated particles of the original nucleus retain or acquire a narrow fringe of protoplasm (of the prevailing tint), and such reconstructed nuclear cells form a class of elements which occur in large numbers. They are less than half the size of the perfect hæmatoblasts, and are therefore easily distinguished; and the nucleus is always cleft, sometimes in the trefoil pattern, but more commonly into four or five pieces. It is difficult to say whether they again grow to be full-sized

hæmatoblasts by the increase of their protoplasmic zone. But the previous history of such elements seems to be beyond doubt; wherever they occur, they show that the production of red blood-corpuscles by detachment or budding has been going on. I shall have occasion to adduce that point of evidence in the cases that follow.

The question arises: Is the mode of origin of red blood-corpuscles from connective-tissue hæmatoblasts the same as, or a guide to the knowledge of, the origin of these corpuscles in the opaque area or in the embryonic mesoblast? That question falls naturally to embryologists, but it may be remarked here that the process of blood formation, when it occurs in the mature organism and in mature tissues, may reveal certain details which are not to be found in the embryonic process, inasmuch as the process in the former case is more deliberate. I shall add the description given by Ranvier for the embryonic formation of blood, as it evidently corresponds, in some points at least, with the account given above. He observes:[1]—"The islets of blood are formed at the expense of certain cells of the primitive vascular cords, which are set at liberty in the interior of the latter in the process of their canalisation. These cells, relatively few in number, are spherical, and contain at first only one nucleus. By and bye this nucleus multiplies, and it proliferates with so great activity that the formative cell of the blood, remarkably enlarged, is transformed into a ball in which all the nuclei seem to touch one another. Later, the ball disentegrates, so as to set free its nuclei with the small quantity of protoplasm that accrues to each. Those are the first red globules of the blood. Their constitution is almost entirely nuclear, and that is the reason why they colour so deeply with carmine." The ball made up of nuclei touching one another is a stage in the process that I have described, but there is a wide divergence in the after stages. There is nothing more certain, in the process which the blood-cyst exemplifies, than that the portions of the divided nucleus have only a temporary and extrinsic connexion with the corresponding portions of the divided protoplasm. The difference between the origin of red blood-corpuscles from connective-tissue hæmatoblasts and their origin from the primitive em-

[1] *Traité Technique d'Histologie*, p. 640.

bryonic cells, would seem to be that the former is direct, while the latter has an additional intermediate stage. But the ultimate product, the red blood-disc, is the same in both; it is not in any sense a cell, but merely a piece of detached protoplasm moulded into a discoid shape.

Red Blood in the Lymph-Sinuses of the Lymphatic Glands (Plate XIV. fig. 4).—At the back of the cystic tumour, and adhering closely to it, was a packet of large lymphatic glands. They were four or five in number, and the largest of them was about an inch long and half an inch thick. Sections of them under the microscope showed the lymph-sinuses everywhere to be crowded with red blood-corpuscles. The blood-corpuscles lay exactly within the limits of the lymph-sinuses. One may conclude, therefore, that they were circulating in the lymph-stream, and that they had been carried to the gland by lymphatic vessels. The presence of red blood-corpuscles in the lymph-sinuses is easily explained. The connective tissue of the region had become a local seat of blood formation, and the blood there produced had naturally found its way into the lymphatic vessels whose radicles are the connective-tissue cells themselves. The blood in the interior of the cyst would no doubt have access in the same way to lymphatics in the cyst-wall.

The lymph-sinuses contained not only dense masses of red corpuscles of the ordinary kind, but also some hæmatoblasts, precisely the same as were found developing from the connective-tissue corpuscles.

Physiological Analogies for the Hæmatoblastic New Formation.—The formation of blood and of blood-vessels is the most fundamental and the most extensive of all the early functions of the ovum and of the embryonic mesoblast. The great blood-forming function of the mesoblast may therefore be claimed as the physiological type of that hæmatoblastic activity of the connective tissue, which has been described in the preceding paragraphs; the connective tissue of a particular region, viz., the neck—itself distinguished as the gill-region for the great extent of its primitive blood-supply—may be said to have returned to its earliest and greatest kind of productiveness. An activity so primitive and so all-important as the blood-forming function of the area vasculosa and of the mesoblast may be said to be the most deeply-rooted

tradition or "memory"—to use the expression of Hering—of that tissue, or to be the tendency handed down from the fœtal period which would be the first to assert itself in any return to the embryonic state of the tissue. While that is the grand physiological analogy of all blood-formation from connective tissue, it is perhaps not the analogy that corresponds most literally in details. The post-blastodermic formation of blood in the subcutaneous connective tissue is a less remote physiological type. That subject has received comparatively little attention hitherto, the most considerable notice of it being a brief account by Schäfer of the development of blood-corpuscles within cells of the subcutaneous connective tissue in the upper part of the fore-limb and in the back of new born rats.[1] Connective-tissue corpuscles, more or less flat, became vacuolated; in some of them the protoplasm had a distinct reddish tinge; others contained one, two, or a greater number of reddish globules, consisting apparently of hæmoglobin. The formation of the hæmoglobin globules reminded one of a deposit within the cell-substance such as occurs in developing fat-cells. These blood-forming cells occurred in regions that afterwards became converted into fat; it was principally in the neighbourhood of the fat-lobules that they were found.

In tracing the development of the fat-lobules that arise in connexion with the breast in the new-born kitten, I have referred to the same appearances as those described by Schäfer.[2] Blood-corpuscles lay near the large vacuolated cells that were about to become fat cells, but it was not easy to decide how the future fat-cells had given origin to them, and my statement was: "Many of the vacuolated cells had the appearance of having given origin in their interior to the red blood-discs that lay near them." The vacuolated cells were without doubt the early stage of fat-cells, and if they had produced the red blood-discs that lay near them, the latter were only a collateral product. I have gone over again my preparations showing the stages of fat-formation from the spindle-shaped cells of the subcutaneous tissue, and I find it difficult to be sure that the red blood-discs are ever contained

[1] "Note on the Intracellular Development of Blood-Corpuscles in Mammalia," *Proceedings of the Royal Society*, 1874, p. 243.

[2] *Report of the Medical Officer of the Privy Council* for 1874, p. 172.

within the vacuoles of the future fat cells. On the other hand, in the earliest stages, before the embryonic cells begin to form the rudiments of the future fat-lobules, the spindle-shaped elements may be seen here and there to have a red blood-disc, as if lying beneath one end of the logwood-coloured nucleus, and the red blood-disc may be taken to be a piece of the protoplasm detached from that end of the cell in a discoid form. At any rate, such appearances are found among the embryonic connective-tissue cells before the vacuolation, which leads to the formation of fat, has begun. It seems probable, therefore, that a more extended study of the process in the subcutaneous tissue may lead to a more comprehensive view of blood formation from connective-tissue cells, and the relation of it to fat formation, than that hitherto arrived at. It is to be observed that Ranvier, describing the formation of blood and blood-vessels in the milky spots in the great omentum of young rabbits, gives an independent support to the view that the formation of the blood-discs is intracellular.[1]

A more special physiological analogy may be found for the hæmatoblastic new formation with respect to its very marked perivascular character. The structure drawn in fig. 1 has a not very remote resemblance to the structure of the coccygeal body and of the intercarotid body. The rounded or elongated heaps of polygonal cells that lie around the wide capillary vessels in both of those structures are, in the representation by Eberth,[2] not unlike the group of cells drawn in fig. 1; there is a further agreement in the circumstance mentioned by Eberth that small groups of the same polygonal cells also occur in the intermediate substance, and away from the vessels. According to Luschka, the coccygeal body is the point of departure of most of the congenital tumours (cystic and other) that occur in the sacral region;[3] and it was conjectured by Luschka that the intercarotid body would in like manner be found to be the starting-point of congenital cysts of the neck. This conjecture was put to the

[1] *Traité Technique d'Histologie*, p. 627.

[2] Stricker's *Handbuch der Gewebelehre*, p. 212.

[3] Henle (*Handbuch der Anatomie*, vol. ii. p. 598) remarks: "While the glandula coccygea cannot be turned to account in physiology, it serves to explain a pathological riddle, viz., the origin of perineal cystic tumours."

proof by Julius Arnold in the case of two congenital cystic tumours of the neck, but he found no reason to associate the tumours with the intercarotid body.[1] It is conceivable, however, and moreover highly probable, that the congenital cysts took origin, as in the case that I have described, from a perivascular tissue in the neck, arising in the same vascular district as the intercarotid body, and of essentially the same structure as that body. The intercarotid body may be considered to be a *survival*, and the formative material of the cystic tumours a *revival* of hæmatoblastic cells. It is well known that the cystic tumours of the neck may be either serous or sero-sanguineous, and I shall show in the next section that cells which are essentially hæmatoblasts may fall short of producing red blood-corpuscles.

Summary.—The beginnings of the new formation are groups of cells chiefly round the walls of blood-vessels in the subcutaneous tissue of the neck. The cells are derived from the ordinary connective-tissue cells, which first assume the spindle-shaped embryonic character, and afterwards take the form of large cubical or spherical or polygonal cells, with a nucleus which stains, and a large peripheral zone of clear or watery protoplasm tinted with the unmistakable reddish-yellow of hæmoglobin. The large hæmoglobin-tinted cells are *hæmatoblasts,* and it is their instability or their tendency to produce red blood-discs from their substance, that leads to the disruption of the solid core of new formation, and to the establishment of a cystic cavity. The walls of the cavity have the structure of granulation-tissue, its villous projections being traversed by wide parallel vessels ending in loops, and the columns of cells being perivascular. The red blood-corpuscles are formed from the zone of hæmoglobin-tinted protoplasm by detachment or by budding, and the detachment of pieces of the protoplasm is accompanied by extensive divisions of the nucleus, the nuclear particles, however, having no share in the composition of the blood-discs. The red blood-corpuscles thus formed from connective-tissue cells in the interstices of the connective tissue may be carried to the lymphatic glands, the lymph-sinuses of the latter being, in fact, full of them.

[1] Virchow's *Archiv.* vol. xxxiii. p. 209.

So far, the observations here recorded form a contribution to the pathology of sero-sanguineous cysts. But, more generally, we have here to deal with a remarkable revival of the blood-forming function of the mesoblast. The case is interesting in itself, but it is still more interesting as revealing the physiological type of certain other tumours that belong more literally to the sarcomatous class, and as illustrating the physiological affinities of the ordinary granulations of repair. The other tumours, together with the granulation structure, will form the subject of the sections that follow.

II. Pathology of Two Cases of Mucous Sarcoma (Sarcoma myxomatodes), one of them Cystic. (Figs. 7 and 8, Plate XV.)

Like the case of sero-sanguineous cystic tumour described in the preceding section, the two cases of mucous sarcoma occurred in the dog in the subcutaneous tissue; one of them, like the sero-sanguineous cyst, occurred in the neck region, and had a cystic interior; the other was seated under the skin of the hip. There is, therefore, a *prima facie* reason for grouping this pair of growths with the case first described. The study of their histogenesis discovers an affinity with that case of the closest kind.

Description of the Tumours.—The tumour that was cystic was removed from a dog at the Brown Institution, London, in July 1875. It lay close under the skin, a piece of skin being removed with it. The fluid in its interior was clear, brownish, and of mucous consistence; there is no record of its microscopic examination. The entire growth had an average diameter of about 3 inches, and the cystic space in its interior was small in proportion to the whole, the walls being at some parts more than an inch thick. The central excavation extended between and behind tuber-like masses on the periphery, so that the solid masses of the tumour might be said to hang, here and there, from the wall of the cyst by a thick pedicle. From these characters the tumour might be at first taken to belong to the class described by Johannes Müller as *Cystoma proliferum*, but it would be erroneous to suppose that the solid masses projecting into the central cavity had grown out from the walls of a cyst

already formed. Cystic spaces, not of regular round shape, but elongated and narrow, were found at several points in the interior of the thick masses round the wall. The solid masses of tumour tissue were soft and almost gelatinous.

The second of the two cases was removed from the hip of a dog at the Brown Institution in February 1876. It lay close under the skin, and it was diagnosed before the operation to be a cyst. It proved to have no actual cystic interior, but its texture was throughout mobile or fluctuating, although it had more the aspect of a fibrous than of a uniformly gelatinous tissue. It was definitely rounded, flattened on its lower surface, and about 2 inches average diameter.

Structure of the Tumours.—The minute structure is the same in both tumours; it is that of mucous sarcoma (*Sarcoma myxomatodes* or *Myxoma medullare*). The non-cystic tumour from the hip has afforded specimens of connective-tissue tumour structure that are unusually well suited to be "show" preparations; but I have, unfortunately, been unable to introduce a drawing from them among the illustrations. Fig. 7, from the cystic growth in the neck, shows the prevailing structure with sufficient accuracy. The cells are large, about three times the diameter of a lymphoid cell or colourless blood-corpuscle, and somewhat flattened on one or more sides. They have a central nucleus and a wide zone of cell-substance which is especially granular at the periphery. Like all mucin-containing elements prepared in the same way, the cells colour quickly and deeply with logwood. Immersion of the sections for a very short time in logwood serves to bring out the characteristic tumour-cells deeply stained, while other cells, in the intermediate ground-substance or in the walls of vessels, are only faintly coloured by so brief an immersion. The arrangement of the cells in longer or shorter parallel rows, as shown in the figure, is characteristic, and is especially marked in the non-cystic tumour of the hip. In the latter, the parallel and regular order of the cells is most remarkable. Tendon-cells among the tendon-bundles, as brought out by gold colouring or by the action of acetic acid, are not more regular. The woodcut which I have introduced on page 30 of this volume, to show the cells of a tendon in a granulating stump, may be taken as

representing, with hardly sufficient clearness, the extraordinary regularity of the cells in this tumour. Where a tract of parallel fibres takes a bend or a waving course, the regular rows of the tumour-cells follow the curve exactly. But for the size and perfect contour of the cells, a section of this tumour might be taken for a section of inflamed tendon. The connective-tissue corpuscles have started up from their concealment among the parallel fibrils, and have assumed the character of tumour-cells; the cells of the connective tissue have undergone important transformations, but they have not been disturbed from their regular and orderly arrangement.

The intermediate ground-substance was, in the cystic case, granular after the tumour had been preserved in the fluids already mentioned, and it was no doubt hyaline when fresh; in the other case the ground-substance was composed either of fibrils or of thicker homogeneous bundles which stained perceptibly.

Tissue-origin and Affinities of the Tumour Structure.—The orderly arrangement of the tumour-cells, especially in the non-cystic case, is in itself enough to show that they have sprung directly from the connective-tissue corpuscles of the subcutaneous tissue. The ordinary cells of the tissue have changed into tumour cells without losing their regular inter-fibrillar position; they do not even appear to have proliferated or to have multiplied by division, but simply to have undergone *in situ* a rapid change in size and form and composition. But there are parts of the tumours, especially of the cystic growth from the neck, where the transformation is less direct, and in which the steps of the process may be made out. Fig. 8 shows the more varied appearances in one of these preparations. At the left side of the figure are a number of parallel spindle-shaped cells; they are connective-tissue corpuscles that have gone back to their embryonic state. The spindle-shaped cell grows in thickness at its central part, and its long thread-like processes come to be stunted projections at the poles of an almost round sphere, and generally visible at one pole only. At the next step the cell is a large round spherical element, with a central nucleus and a broad zone of protoplasm. The protoplasm has at the same time acquired *the reddish tinge of hæmo-*

globin, and the cells have all the characters of the *hæmatoblasts* described in the last section. If there be any difference, it is that the hæmoglobin-tinted protoplasm of the cells in these cases, destined to a further mucous transformation, may be said to be in some cases bounded by a delicate sac-like cell-wall, while in the other hæmatoblasts the reddish protoplasm adhered round the nucleus without any restraining membrane or pellicle.

That we have here to deal with the same function or activity of the embryonic connective tissue as in the former case is further shown by the presence of red blood-corpuscles scattered around the cells, and by the evidences of their detachment from the reddish protoplasm of some of them. It would have been difficult to collect, from the present pair of tumours, a group of hæmatoblasts such as are figured from the first case in the upper part of Plate XIV. Equally good instances of hæmatoblasts in the process of breaking up into red corpuscles might not have been found, partly because they are much less abundant; but the figures of entire and perfect hæmatoblasts might have been taken as well from the former cases as from the latter. It is always difficult, in the prepared tissues, to find the actual steps of any cell transformation, and the tissue described in the first section must be considered unusually favourable for that purpose. But in the second pair of subcutaneous tumours the process may be followed with sufficient certainty with the help of those indications which the case of sero-sanguineous cyst supplies. I have referred to a numerous class of cells, with nucleus divided into three or more pieces, and with a narrow fringe of reddish protoplasm; they were what remained of hæmatoblasts that had detached the greater part of their protoplasm in the form of red blood-discs. Their occurrence was taken as showing that the formation of blood-discs from hæmatoblasts had been going on. The very same cells occur in considerable numbers in the preparations from which fig. 8 is taken, and red blood-corpuscles occur beside them. We may therefore claim to have found, in the present cases, the same evidences of red blood formation from embryonic connective tissue as in the case of the sero-sanguineous cyst. The tendency, at least, to blood formation is there.

But the resemblance is only in the initial stages of the

hæmatoblastic process. The large polygonal cells in the present pair of cases are, for the most part, hæmatoblasts only for a point of time; by far the greater number of them do not go on to detach their protoplasm in the form of red blood-corpuscles, but, preserving their entirety, they undergo a mucous transformation—their substance becoming granular—which turns them into the characteristic cells of the tumour structure. The hæmatoblastic function of the embryonic connective tissue is clearly manifested, but it is manifested only for a point of time, and it is then diverted from the physiological track and into a track which is purely pathological. The cells of a sarcoma myxomatodes may be traced back to a point in their history where the physiological type is clear, but they are themselves elements which have no physiological analogy. In the case of the sero-sanguineous cyst, the revived blood-forming function of the connective tissue was carried on the whole to a normal issue; the cystic tumour no doubt existed as such, but a new formation came into existence, not so much because the activity that the connective tissue of the part took on was abnormal, but because the access of blood-forming activity came to it long after the time for local blood formation was past, and in the midst of tissues that were fixed in their adult structure and functions.

Summary.—The two tumours described in this section are perfect examples of connective-tissue or sarcomatous new growths; the cells are large nucleated elements with partly rounded and partly flattened sides, regularly placed in the interstices of the ground-substance; the ground-substance is in the one (cystic) case hyaline, and in the other case chiefly fibrillar; the cells and ground-substance show the mucous reaction very clearly, and one of the tumours developed a cystic cavity filled with mucous fluid. The tumours are exquisite types of *Sarcoma myxomatodes.* But, when we have satisfied the legitimate desire to place the tumours in their class, we are entitled, on the evidence of their tissue-origin, to add that their elements have passed through the phase of hæmatoblasts; that in certain places the cells may be detected in large numbers, showing the perfect character of the hæmoglobin-tinted cells described in detail in the last section, and that a certain number

of the primitive cells appear to have actually adhered to the physiological destiny of hæmatoblasts and to have given origin to red blood-corpuscles. The two cases of *Sarcoma myxomatodes* are therefore in their early history illustrations of the blood-forming function of the connective-tissue cells or of the embryonic mesoblast.

III. Pathology of a Subcutaneous Cyst of the Back, with Granulation-like Interior. (Fig. 6, Plate XIV., and fig. 9, Plate XV.)

Description of the Cyst.—This growth occurred under the skin between the scapulæ in a middle-aged man, and was removed by Dr Humphry at Addenbrooke's Hospital in October 1879. It was about the size of a walnut, and contained a turbid brownish fluid. It was not encapsuled, its periphery, as removed, being formed in an indefinite way of somewhat dense connective tissue, largely occupied by fat. Its interior was for the most part uneven or irregularly trabeculated or frayed out; but on one side there was a loculus or recess which was covered with a thick layer of scales. The occurrence of epidermic-like scales in the interior of a cyst is admittedly no evidence that the cyst is formed from sebaceous glands by the retention of their secretion. Cysts that are more distinctly atheromatous or sebaceous or dermoid than the present case are known to form as independent new growths in the depths of the subcutaneous tissue, and, as regards this cyst, there is no suggestion whatever that it belongs to the class of cysts by retention.

Structure and Affinities of the New Growth.—The new formation forming the wall of the cyst was in some places a quarter of an inch thick. The structure is shown in fig. 9, Plate XV. The structure is that of granulation-tissue, and it is on the whole not unlike the granulation-tissue of a granulating surface. I have compared the preparations from the wall of this cyst with preparations from a granulating stump of the leg (which failed to cicatrize), and I can find no very marked points of difference. In both cases there are granulation-cells, consisting chiefly of a very granular nucleus with little or no clearly differentiated cell-substance, and the cells are clustered round the walls of

vessels. The vessels are the usual wide vessels of granulation tissue, of simple capillary structure, running with a parallel course towards the surface, and there joining with one another in loops. Even in the deeper strata, where the formative process extends into the subjacent connective tissue in narrow tracts, the appearances from the granulating stump are much the same as those in the cyst wall. The first impulse is to ascribe the granulation structure round the wall of this cyst to an "inflammatory" irritation somehow set up, and so to reduce it to a category that is at least very familiar. But a subcutaneous cyst enucleated by operation is not an abscess, and from first to last in this case there did not appear to have been present either the redness, or the heat, or the pain, or the swelling of inflammation. The true analogy for the cyst is not the interior of an opened abscess cavity, but the interior of the sero-sanguineous cyst described in the first section. The analogy of the reparative process that follows inflammation lies no doubt near at hand, but the process is not so much intelligible in itself as it is familiar. The occurrence of a sero-sanguineous cyst is a comparatively rare event in the organism, but when that process is set up, it carries us nearer to the fountain-head of physiological activity, and may serve actually to throw light upon so common a process as that which occurs in a granulating surface. The interior of the sero-sanguineous cyst had also the granulation character (fig. 3, Plate XIII.),—wide vessels of simple capillary structure running in a parallel direction towards the surface, and there forming loops with one another, and cells grouped closely round the walls of the vessels. In the deeper layers there are precisely the same scattered centres of perivascular cells as in the deeper layers of the granulation-like interior of the present cyst, or of the analogous granulating surface. Again, in the granulation-structure of the sero-sanguineous cyst, there are riper cells and cells less mature. The former are found farthest from the walls of vessels, in the intervals between the granulation-like vascular tufts, and on the free extremities of the same. It is in those situations that the *hæmatoblasts are most active in forming blood*, and it is in the analogous situations that the granulation cells of a granulating surface *are most active in forming pus.*

The cyst with granulation-like interior does not, however, form

pus. On the other hand, it forms blood. If reference be made to the large drawing of the structure of the cyst-wall (fig. 9, Plate XV.), it will be observed that the dense columns of granulation-like cells round the walls of vessels alternate with lighter spaces where the cells are larger and less deeply coloured. The cells in the lighter spaces are not all the same in size and form, but they all belong to the same class. They grow out of the ordinary perivascular cells of the tissue, becoming larger and at the same time differentiating their nucleus from the zone of protoplasm. The zone of protoplasm acquires a yellowish tint, and the cells become in all essential respects *the same as the hæmatoblasts of Section I.* Several examples of them are given in the lower part of Plate XIV. fig. 6. Their protoplasm has never the clear and watery characters of the hæmatoblasts in the blood-cyst, and the colour is not so exactly the reddish colour of hæmoglobin. Their substance is more yellow in tint and more granular, but it breaks up, none the less, into red blood-corpuscles. The red blood-discs are not budded off from the side of the cell, as in the remarkable process of cell-disintegration before described, but the whole cell—the nucleus being driven to one side or having become invisible altogether—seems to fall to pieces as a heap of blood-corpuscles. I have counted as many as fifteen or twenty red blood-discs in a round compact heap remaining from the break-up of one of the larger cells. With these differences, we detect the same hæmatoblastic function in the cells of the granulation-like cyst-wall as in the cells of the sero-sanguineous cyst. In both cases the great blood-forming function of the embryonic mesoblast tends to assert itself.

The origin of the surface scales that occurred over a certain part of the wall of the cyst is a point of collateral interest, but, as the evidence is clear, the subject may be noticed here briefly. The scales were large flat cells, like those found in the transition from skin to mucous membrane. The deeper rows of them were cubical. In the sections of the entire cyst-wall the transition stages of the surface scales could be traced down to the ordinary granulation-like cells. The same class of cells, which enlarged to form hæmatoblasts and angioblasts, underwent a change in another direction to become the flat cells of the surface.

Blood-forming Function of Embryonic Cells in Inflammation.

—Before pointing out the claims of the granulation-like interior of this cyst to be considered as a granulation-like sarcoma (Rindfleisch), or a round-celled sarcoma (Virchow), I shall quote from Professor Stricker (*Vorlesungen über Allgemeine und Experimentelle Pathologie*, Wien, 1877–79) certain remarks on the formation of red blood-corpuscles in inflammation. At page 309 he observes:—"But I must at once add that not all the red blood-corpuscles which one meets with in inflammation-centres have escaped from the blood-vessels. Everywhere in centres of inflammatory action red blood-corpuscles may arise from colourless elements, just as is the case in the embryo." And recurring at page 436 to this subject in greater detail, he says:—"It remains for me still to speak of the new formation of red blood-corpuscles in inflammatory centres. . . . Opinions differ as to the way in which the new blood-vessels develop. But, as regards the blood which enters the new vessels, there is a general opinion that it comes from the old vessels. In so far as the new-formed vessels are already taken into the circuit of the circulation, that is a matter of course. But in newly vascularised tissues there are also vessels which are not yet joined on to the circulation, which are still blind sacs, and nevertheless contain blood-corpuscles. Whence come these elements? I have been enabled, in the cornea of the frog as well as of the rabbit, to prove the new formation of blood with all conceivable certainty. . . . Two facts may be determined for certain from such corneas [in which pannus had been artificially set up]. First, that there were present formed elements with a quite obvious colour, although in many places they had the character of colourless cells, viz.: they were finely granular, they had a remarkable irregularity of surface, and an apparent closeness of texture. Such young forms of red blood-corpuscles lay partly free in the midst of the inflamed corneal tissue, and in part they were contained in the closed saccular blood-vessels. Secondly, it appeared that, in the inflamed cornea, blood and blood-vessels are formed exactly as Klein has seen them forming in the embryo chick, viz.: in the larger elements blood-corpuscles are produced endogenously, while the coat of the cell becomes the wall of the vessel. . . . Having shown you that in inflammation-centres red corpuscles arise from colourless cells, I must

now add that this transformation first sets in when the inflammatory process has lost in intensity. So long as the process is of a very tempestuous kind, so long as the new-formed cells divide rapidly, blood-formation is not attained to. The formation of blood is rather, as I have already emphasised, an accompaniment of the new formation of tissue."

Giant-Cells as Vaso-Formative Cells.—Scattered among the cells in the lighter intervals of fig. 9, which I have classed as hæmatoblasts, are a number of multinuclear elements that grow out of the other cells through transitions such as are represented at the foot of Plate XIV. fig. 6. The larger of them are exquisite examples of giant-cells, with a circlet of nuclei round their margin. The vaso-formative character of such cells has been pointed out by Brodowski, Ziegler, and others, and, in a former paper in this *Journal*,[1] I have shown that precisely the same kind of cells occur in the deeper strata of the placenta (of the guinea-pig), and that they are the direct means by which the wide blood-channels in the deeper parts of the placenta are formed. The controversy about the origin and significance of this kind of giant-cell in morbid products still goes on. I shall rely upon my former demonstration of their exact physiological type in the placenta, and accept, without any hesitation, the doctrine that they are vaso-formative cells or angioblasts (Brodowski). The lowest of the group of cells in fig. 6 is a giant-cell, from which the granular protoplasm of the interior has fallen out, leaving merely a peripheral row of nuclei; the cell lies in the preparation close to the entire giant-cell above it in the figure, and there is no doubt that the lower of the two represents the excavated condition of vaso-formative giant-cells. The central substance has generally the yellowish-brown colour represented (of somewhat too deep a shade) in the figure, not differing markedly from the tinted cell-substance of hæmatoblasts. The central substance of the giant-cell doubtless breaks up, in many instances, into a mass of red blood-discs, but there are cases in which it seems to fall into a condition of granular detritus.

[1] "Further Observations on the Formation of the Placenta in the Guinea-pig," and "The Physiological Type of the Giant-cells of Tubercles and Granulations," vol. xiii. p. 173. The second of the two papers contains an account of the observations of Brodowski, Ziegler, and others.

We thus detect in the embryonic connective-tissue cells that form the wall of this cyst, not only a tendency to form blood-corpuscles, but also a tendency to form blood-vessels, and those tendencies may be said to be a clear expression of the earliest and most deeply-rooted function of the embryonic mesoblast.

Granulation-like Interior of the Cyst considered as Granulation-like Sarcoma.—The kind of connective-tissue cellular growth which Virchow called a small round-celled sarcoma has been named by Rindfleisch a granulation-like sarcoma. The latter observes—"The structure of the round-celled sarcoma differs only quantitatively from that of granulations. The vessels are in part wider and thicker in the walls; but where they pass into capillary vessels, the latter are as delicate—often formed of only a single layer of cells—as we saw the vessels of granulations to be. The intervals between the vessels are everywhere uniformly filled with the round cells and the soft and formless ground substance of the embryonic tissue." That description of a round-celled sarcoma evidently corresponds to the structure of which the wall of the cyst was composed (see fig. 9). The tumour may be regarded as a round-celled sarcoma that has become cystic; and the fact that the spindle-celled sarcoma to be described in the next section underwent the same cystic excavation, and showed in part the same kind of attenuated cyst-wall, will serve by analogy to show that the designation of a round-celled sarcoma become cystic is as appropriate as that of a cyst with granulation-like interior.

IV. Case of Spindle-Celled Sarcoma with Cystic Interior, from the Head of a Dog.

The mode of formation of the cystic cavity in the tumours already described, has been taken to be that an originally firm core of new-formed tissue has undergone disruption and central softening, as in an abscess. The tumours would be considered in the first instance as solid centres of new growth in the subcutaneous tissue, and the actual new growth that forms their walls—of considerable thickness in some cases—may be justly regarded as the kind of new growth of which the once solid mass consisted, and as supplying the structural indications for

placing the tumours in their respective classes. The one doubtful case is the cyst with granulation-like interior; but it so exactly resembles the hæmatoblastic tumour, both in the perivascular grouping of the cells and in the granulation character of the interior, that it may also be classed as a new growth, in the proper sense of the term, as distinguished from a product of inflammation, and more particularly as a round-celled sarcoma which has become cystic. I shall describe briefly in this section another case of sarcoma become cystic, which may serve to illustrate the process of cystic excavation in the other cases.

The tumour was removed from the head of a dog at the Brown Institution in July 1875. The cavity was filled with a clear brown fluid, of which I made a microscopic examination while it was still warm. The fluid contained a number of cells of very large size, remarkable for their active amœboid movements. The round contour of the cell became studded at various points with short processes of the protoplasm, which were again withdrawn, to reappear at other points. The cells were much larger than ordinary amœboid cells, and might, indeed, be said to be amœboid giant-cells. Their substance appeared to be uniformly granular, and was colourless. It was conceivable that they were concerned in the cystic excavation, in some such way as osteoclasts are said to perform the office of bone absorption; but it was difficult to identify the cells, or to detect any evidences of that function, in the sections of the prepared tumour.

The interior of the tumour presented a very remarkable and beautiful appearance. The actual free space in its centre was not large in proportion to the size of the whole growth. On its superficial aspect, next the skin, the tumour was thinned away to a mere membrane, about a line thick, and the surface there presented a finely nodulated appearance. The deeper side of the growth was nearly an inch thick at its thickest part, and the substance thinned off towards the upper side. All round the sides of the central cavity, except at the most anterior part, there was an intricate network of rounded trabeculæ, about a line or two lines in thickness. They seemed to hang into and to cross the central space of the tumour, or, more especially, the hemispherical recess of its posterior segment, like stalactites in a cave. The surfaces of the trabeculæ were perfectly rounded and

smoothly polished, and the free ends of the numerous broken or incomplete trabeculæ were in like manner rounded and smooth. There was no doubt that this was a solid tumour undergoing a very gradual cystic absorption. The structure of the tumour was that of a small spindle-celled sarcoma. In the midst of the solid masses on the posterior wall, slit-like spaces were forming, and the mode of formation was as follows:—The spindle-cells became globular, the nucleus excentric, and the protoplasm watery, so that they came to resemble, in form at least, the hæmatoblasts represented in Plate XIV. The long and narrow crevices in the midst of the solid substance were evidently made by the deliquescence of these globular cells.

The more immediate point of interest is the condition of the attenuated cyst-wall next the skin, corresponding to the situation where an abscess would point. Sections of the thin membrane-like wall showed, on the whole, a remarkable resemblance to the general condition of the wall in the cyst with granulation-like interior described in Section III. The superficial layers of spindle-cells had become flattened so as to resemble epidermis, and the cells of the substratum were grouped in papilliform or granulation-like columns. There were also sometimes multinuclear cells among them, which seemed to be pieces of the nucleated intermediate ground-substance, but here and there they presented very much the same characters as the vaso-formative giant-cells that occurred in the other case. The spindle-celled sarcoma was reduced to the extreme degree of thinness only on its upper surface, while the round-celled growth was uniformly attenuated all round. That is the chief point of difference between them, and it seems reasonable, from the analogy, to describe the cyst with granulation-like interior as a round-celled sarcoma that has become cystic.

It would be a somewhat far-fetched addition to the argument to adduce the spindle-cells of this tumour as illustrating, in their deliquescence, the hæmatoblastic function of the embryonic connective tissue. The case is an instructive member of the series, as occurring in the subcutaneous tissue of the head or neck, and as undergoing the process of cystic excavation, although it was of firm spindle-celled texture.

V. Review of Five Cases of Subcutaneous Cystic Tumours, and of Miscellaneous Cases.

Of the five cases that form the subject of this paper, two may be taken as perfect examples of *Sarcoma myxomatodes*, one has the main features of a granulation-like or round-celled sarcoma, one is a good example of sarcoma made up of small spindle-cells, and one, if it be called sarcomatous at all, is a "hæmatoblastic" sarcoma. The last mentioned is so unstable in its texture, that its connective-tissue affinities are apt to be overlooked and its character as a sero-sanguineous cyst alone noticed; but the other cases, which may be fairly reckoned sarcomatous tumours, are also cystic. It is the cystic characters of the group which make them more or less imperfect specimens of sarcoma for classification purposes, but it is from their cystic characters that they derive their interest for general pathology. Although, from one point of view, these tumours are subcutaneous cysts, they are from a more comprehensive standpoint new formations springing from the connective-tissue cells, and illustrating the physiological activity of those cells. It is because the connective-tissue elements, of which they consist, manifest a certain instability, that they have become cystic in varying degrees, and that instability of their elements is the character which brings to light their somewhat obscure physiological relations. The instability reaches its highest point in the hæmatoblastic formation, and the issue is in that case a sero-sanguineous cyst. In the cyst from the back, with granulation-like interior, the unstable quality of the connective-tissue cells to which the cyst is owing, is not so purely of the physiological type as in the first case; there are obvious points of affinity with the hæmatoblastic disintegration, but there are also points of affinity with the disruption of a hard core of tissue of inflammatory origin. In the two cases of mucous sarcoma, the cells are as if preserved from the fate of true hæmatoblasts to undergo a subsequent disintegration, of the mucous instead of the sero-sanguineous kind. In the case of the spindle-celled sarcoma, the growth corresponds so perfectly in structure to the ordinary persistent and durable type of tumour, that it is difficult to understand why its elements should have become in any degree unstable.

It is not for nothing that these new formations of the subcutaneous connective tissue are liable in common to cystic disintegration. The type of the instability of their elements is found in the sero-sanguineous cyst, where the firm new growth breaks down in accordance with the strict physiological law of blood-formation. The destiny of the cells in that tumour is completely fulfilled, and red blood-corpuscles are formed in enormous numbers. The same ripening of cells towards their physiological destiny is seen in the lighter spaces of the granulation structure in the cyst from the back. In the cases of mucous sarcoma, the cells are all hæmatoblasts for a point of time, but the normal fate of hæmatoblasts is avoided, and the cells preserve their integrity, with the liability, however, of a subsequent mucous instability. The spindle-celled tumour remains for the most part solid and enduring, but where it does develop spaces in its interior, it is from the spindle-cells becoming globular in form and watery in substance, and therein following in the track of the unstable connective-tissue cells of the other cases. The last mentioned case shows only in the most remote degree, if at all, the evidences of a tendency towards blood-formation in its connective-tissue elements; but the other cases show such a tendency in the most direct and obvious manner. That which distinguishes them and links them together is the tendency—it may be subordinated but still present—of their connective-tissue elements to form blood. The peculiarity which runs through or underlies the tumour process in these cases is the more or less clearly asserted blood-forming function of the embryonic connective-tissue cells. The blood-forming function is the earliest and greatest function of the mesoblast; it may be said to be the most deeply-rooted tendency of embryonic connective-tissue cells, or the "memory" of an earlier period which is most strongly retained. It is not asserted that the revival, in post-embryonic times, of this great function of the connective tissue is the reason why tumours arise in the connective tissue, but it may be truly said that the revival of embryonic activity in the connective tissue, to which the tumours of that tissue are referable, is apt to bring to the surface the greatest and most elementary aspect of its activity, viz., that of blood-making.

Miscellaneous Cases of Sarcoma.—I have endeavoured to make good that point in the cases above described. But the indications of the hæmatoblastic function in connective-tissue new growths are much more widely scattered, and may, indeed, be detected in many of the sarcomatous tumours that come under notice from day to day. Of such cases, I shall mention, in the briefest way, three lately examined by myself. One was a tumour of the interior of the cerebral hemispheres, which was gelatinous, diffluent, and streaked with patches of black blood. A piece of the firmer part of the growth was hardened with some difficulty, and it showed the structure to be that of the round-celled sarcoma proper to this region, or the glioma of Virchow. The portion examined did not include any of the hæmorrhagic areas, but the round cells showed here and there the characteristic appearances of hæmatoblasts, and there were present everywhere the evidences of extensive local formation of the blood. Another case was a definitely bounded oval growth from aponeurosis or periosteum over the back of the scapula in a man aged 70. The cut surface showed certain occasional lines or streaks of reddish-brown colour, but the tumour was to the naked eye everywhere firm; it was divided into lobules by thin septa of connective tissue. It proved to be a round-celled sarcoma of, on the whole, very compact structure, but traversed in some regions by narrow lacunar spaces which contained red blood-corpuscles. The blood seemed to have been formed within the spaces in which it lay, and there were here and there seen enlarged cells of the tumour, near the margin of such spaces, which were filled with yellow pigment granules. The third case was a very extensive and deeply lobulated tumour in the upper and outer part of the thigh of a boy, attached to the fascia lata and muscular aponeuroses, and extending deeply into the space between the tensor fasciæ and the vastus externus. It was removed by operation. The structure was that of a spindle-celled sarcoma; and although the cut surface appeared to the naked eye to be quite uniform and compact, subdivided only into lobules of unequal size, yet the microscopic sections showed it to be traversed everywhere with lacunar spaces, mostly narrow and elongated, but sometimes round. These spaces were lined with a row of cells like the more flattened kind of columnar

epithelium; the cells were mere surface modifications of the prevailing embryonic spindle-cells. The lacunar spaces sometimes contained blood-corpuscles, and I have observed here and there the epithelial-like cells of the surface enlarged to the size and form of a hæmatoblast, as already described, and to still larger vesicles, and evidently about to break up either into a mucous fluid or into some other product. The blood that lay in these spaces was, no doubt, produced within them. Both this spindle-celled tumour and the round-celled tumour preceding it may be loosely compared to extensive collections of embryonic mesoblast, in which blood-islands or blood-spaces are formed from the transformation of some of their cells. The remarkable appearances of lacunar spaces filled with blood, in the substance of these tumours, and especially throughout the whole substance of the spindle-celled tumour, reminds one of nothing so much as the illustrations of the *area vasculosa* in embryological textbooks.

Melanosis of Spindle-Celled Sarcoma.—Those three cases happen to be the last cases of sarcoma that I have preserved and examined, and, curiously enough, they all show reliable evidences of that mesoblastic blood-forming function which the series of cystic cases exemplified more perfectly. The melanosis of some spindle-celled sarcomas (not including those of the choroid) is a suggestion of the same sort. In the early stage of the mucous sarcomas described in Section II., there are perfect examples, as regards shape, of the large spindle-cells which are usually found in the melanotic tumours of the subcutaneous tissue (growing perhaps from the scar of an old chronic ulcer), and small groups of them here and there have their substance filled with bright yellow pigment grains. There is a point of time in the development of the mucous sarcomas of Section II., at which their cells might have followed the ordinary destiny of hæmatoblasts, as in the sero-sanguineous cyst; and it may be said also, that there is an earlier point of time in their history at which they might all have become large spindle-cells filled with pigment, as in a melanotic spindle-celled sarcoma.

Fungus Hæmatodes and other Internal Sarcomas of Bone.—In still another large class of sarcomatous tumours, those taking origin within the medullary canal of bones, it may be con-

fidently expected that evidences of a hæmatoblastic activity will be found in the embryonic cells developing to form the tumour. Those internal tumours of bone, as distinguished from the external or periosteal, correspond for the most part to the great class of *fungus hæmatodes*, or encephaloid, or myeloid. They are often cystic, containing either blood or colloid substance in their cystic spaces. There is every reason to expect that both the blood and the colloid fluids are referable in the last resort to the deeply-rooted hæmatoblastic tendency of the mesoblast, or of the embryonic connective-tissue cells. The internal sarcomas of bone are in some way related in their origin to the marrow of bone, and the marrow of bone is a mesoblastic tissue that retains its embryonic characters and its blood-forming function to a comparatively late period of extra-uterine life, and, moreover, exhibits in after life a readiness to return to its early function, under conditions such as those of pernicious anæmia.

VI. Disordered Function as a Cause of Tumours.

Professor Cohnheim has devoted the chapter on tumours in his *Lectures on General Pathology* to a brilliant exposition of a doctrine of tumour formation which may be said to be his own. With a wealth of illustration seldom surpassed, he maintains the proposition that the tumours of the body are due to the awakened growth of embryonic rudiments that have remained over from the earliest periods of development, and have lain long latent in the midst of the mature tissues. Many of us die, he observes, with such rudiments in our bodies, which have, fortunately, never grown to be tumours. He prefers the hypothesis that portions of embryonic tissue are actually present, scattered throughout the body, to the alternative hypothesis that the tissues of the body may revert, on occasion, from their adult condition to their embryonic condition.[1] By way of filling in the details of this hypothesis, he supposes that more embryonic tissue has been furnished for the particular part or organ than has actually been used up;[2] that the unused surplus has remained in its embryonic state embedded in tissues no longer embryonic; and

[1] *Vorlesungen über Allgemeine Pathologie*, Berlin, 1877, p. 649.

[2] *Ibid.* p. 635.

that such remnants, when they are stimulated to grow, naturally form tumours in the respective localities or organs to which they belong. The tumours of the body may thus in a sense be regarded as a subdivision of *monstra per excessum*, although the latter, properly so-called, differ in being commonly congenital.[1]

The objection that will be taken most widely to this hypothesis is that it is too exclusive. Whoever has at any time sought to attribute the origin of a tumour or tumours to a cause other than the proliferation of embryonic rudiments of tissue, will naturally feel that the hypothesis of Cohnheim is too wide. So comprehensive a hypothesis must needs swallow up many independent fragments of theory, as the rod of Aaron swallowed up the rods of lesser soothsayers.

There is one great class of tumours for which the embryonic hypothesis is superfluous. It is not necessary to call in the aid of surviving embryonic rudiments to explain the tumours of secreting structures. A cause less remote, and residing, in fact, in the every-day activity of such organs and parts, may be found for the tumour diseases to which they are liable. In treating of the physiology and pathology of one secreting organ, the breast, I have endeavoured to explain its tumours as arising from disordered function,[2] and that explanation does not stand as a hypothesis, but as an induction. The rationale that is applicable to tumours of the breast may be applied also to the tumours of other secreting structures, and notably to those of the stomach; and if the element of disordered function is not so clearly traceable in the tumour disorders of other epithelial parts and of the skin, that may be attributed to the circumstance that a function, in the strict sense of the term, cannot be asserted for them,[3] and that, in consequence, their normal activity does not afford a working physiological paradigm for their morbid products, such as one may construct for the epithelial secreting structures.

If, then, the hypothesis of embryonic tissue rudiments be superfluous for the great class of tumours in secreting structures and other epithelial parts, it loses the unity or universality by which

[1] *Vorlesungen über Allgemeine Pathologie*, Berlin, 1877, p. 650.

[2] *Contributions to the Physiology and Pathology of the Breast*, London, 1878. See also a paper on "Scirrhus of the Breast" at p. 29 of this volume.

[3] Virchow, *Cellular Pathologie*, chap. iii.

it stands or falls. It would probably be a mistake to formally claim for the principle of disordered function in tumour formation that unity or universality which the principle of embryonic tissue-rudiments appears to fall short of. But it may be not without instruction to try how far the principle of disordered function will go in accounting for the origin of tumours in general. To that end it will be desirable to give to the word "function" as wide a significance as possible. For secreting structures like the breast, the function is the activity of the organ —periodical in this particular case—throughout the mature life of the individual, and for epithelial parts like the œsophagus or rectum, the function is the analogous, but less easily estimated, activity of the epithelial cells. But what are the functions of the great series of connective tissues? It is here that an interpretation of the word function, wider than the conventional interpretation of it, becomes necessary.

In a former paper on "A Pathological Function of Periosteum,"[1] I observed: "But there is one variety of the connective tissue that may be said to be endowed with a function," viz., the periosteum with its bone-forming function; and I endeavoured to show in the course of the paper that a sarcomatous tumour of the metatarsus in a rickety subject had owed its origin to a disorder of the osteoblastic function of the periosteum round the fifth metatarsal bone. The disorder was further traced in detail to the well-proved rachitic disposition of the patient, a girl, aged 18.

While the function of a secreting organ is its productive activity throughout life, the osteoblastic function of periosteum is proper only to the growing period. As regards a secreting organ, the contention is that a tumour may result if the function fails or errs in any way in the course of its ordinary activity. (In the case of the breast, as I have elsewhere emphasised, it is the *obsolescence* of the organ, and of its function, at the climacteric period that is the most frequent occasion of the tumour-formation in women.) As regards the periosteum, a tumour involving its osteoblastic function may occur in the ordinary course of that function during the growing period, or the tumour may occur after the growing period is over, and, in fact, *from the*

[1] This *Journal*, vol xiii. April 1878.

re-awakening of a past function. Still more is the re-awakening of a past function to be called in if the principle of *functio læsa* is to be extended to other varieties of the connective tissue. By going back beyond the growing period, and to the time of embryonic development, we may discover still other functions of the connective tissue, or other functions of the mesoblast. The periosteal variety of connective tissue (embryonic in character) carries its osteoblastic function into the growing period and then drops it, but there are functions of the connective tissue which cease within the embryonic period itself. The earliest and greatest of these, as I have before remarked, is the blood-forming function of the mesoblast; and it is with the re-awakening of that function in post-embryonic life that I identify the beginnings of the sarcomatous tumours described in the foregoing paper.

If then, following the example of Professor Cohnheim, we attempt to apply as widely as possible the particular principle—viz., that of *functio læsa*—to tumour-formation, we will conclude that one great class of tumours, those of secreting structures and other epithelial parts, are perversions of the function in the ordinary course of its activity, and that another great class of tumours, those that form in the connective tissues, are perversions of function, with the difference or the addition that the function has been re-awakened after its normal period of activity is long past.

For connective-tissue tumours, it is obvious that the embryonic activity of the tissue must be admitted into any and every hypothesis of their origin. The hypothesis of Cohnheim asserts the actual survival of portions of embryonic tissue among the mature tissues, and it rejects the alternative view that the survival is not of actual embryonic tissue, but of the tendency in the mature connective tissues to revert, on occasion, to their embryonic character. The latter idea is not unfamiliar to pathologists,—Professor Cohnheim invests it with needless mystery by speaking of it as the "Mauser-und Verjüngungs-theorie von Schultz-Schultzenstein und Stricker,"—and it is preferable to the notion of persisting actual germs of embryonic tissue, in so far as it is supported by a good deal of observation, while the other is mainly unsupported. Now, the reversion of connective-tissue cells to their embryonic characters is, in a sense, a re-awakening of their past

function. In the cases which I have described in this paper the return to the embryonic state is bound up with a more or less obvious manifestation of function, viz., the blood-forming function. The re-awakened function may adhere closely to the physiological track, as in the case of sero-sanguineous cyst of Section I., or it may depart from that track, as especially in the cases of *Sarcoma myxomatodes* of Section II.

How wide the interpretation of the word "function" requires to be, becomes apparent when we speak of the functions of the mesoblast. Blood and bone are definite products of its functional activity: hæmatoblasts and osteoblasts are as distinctly the functional condition of mesoblastic cells as if they had been the productive cells of a secreting organ; and it is to the blood-forming and bone-forming activity of the embryonic connective tissue that the cases in this paper, and the case in a former paper, relate. But, after blood and bone, the actual functional products of the mesoblast become more subtle or more difficult to estimate. The whole process of development is, in a sense, a function of embryonic cells. I have endeavoured to show, in treating of "the development of the mammary function," that the mature function of the breast is, in effect, a sustained repetition of those cellular changes which the embryonic cells went through in order to become the breast (*op. cit.* chap. v.) Even in development we cannot separate the ideas of formative and of functional activity. They are the correlated aspects of the cell-life of the body. The hypothesis of tumours growing from embryonic tissue-rudiments is a mere proliferation hypothesis, a facile resort to the commonplace idea of cell-division; but the hypothesis of a reversion of connective-tissue cells to their embryonic character is a hypothesis that takes due account of embryonic function. The new growth starts, not from a material quantity of embryonic tissue, but from a force that produces embryonic tissue out of the ordinary cells of the body. It is a return to the original spontaneity of the ovum and of the embryonic tissues, and a re-awakening of a past function, in the widest sense of the term.

EXPLANATION OF PLATES XIII.-XV.

Plate XIII.

Fig. 1. Structure in the deeper parts of the wall of sero-sanguineous cyst: large polygonal cells grouped round vessels of capillary structure. The cells have the colour of hæmoglobin (× about 400).

Fig. 2. From the wall of sero-sanguineous cyst: origin of hæmatoblasts from embryonic connective-tissue cells; breaking-up of the hæmatoblasts into red blood-corpuscles (see text) (× 350).

Fig. 3. Inner surface of sero-sanguineous cyst; parallel vessels of capillary structure running to the surface, and there forming loops, as in granulation tissue; perivascular grouping of the hæmatoblastic cells (× 150).

Plate XIV.

Fig. 4. From lymphatic gland adhering to under surface of sero-sanguineous cyst; *a*, follicle; *b*, lymph-sinus filled with red blood-corpuscles; *c*, trabecula (× 350).

Fig. 5. Hæmatoblasts from the surface of sero-sanguineous cyst: in one of the lower rows are several entire hæmatoblasts; most of the other cells are in process of detaching their protoplasm in the form of red blood-discs with extensive division of their nuclei and dispersion of the nuclear fragments (× about 700).

Fig. 6. Group of cells from granulation-like tissue forming wall of cyst (see Section III.); in the upper row, cells with one nucleus, resembling hæmatoblasts; cells with four nuclei, and a giant-cell with a circlet of nuclei; under the latter, a giant-cell with its granular central protoplasm fallen out (× about 700).

Plate XV.

Fig. 7. Structure of *Sarcoma myxomatodes* (the cystic case of Section II.) (× 350).

Fig. 8. Initial stage of *Sarcoma myxomatodes:* embryonic connective-tissue cells (spindle-shaped) becoming spherical; their protoplasm in the earlier stage being watery and hæmoglobin-tinted, and in the ultimate stage of tumour-cells, being granular and capable of deep logwood-staining. A few cells with nucleus much divided, as in the hæmatoblastic process (× 350).

Fig. 9. Structure of cyst-wall in case described in Section III.; granulation-like tissue; wide parallel vessels; perivascular cells. In the lighter spaces occur such cells as are drawn in fig. 6 under higher power; some giant-cells among them (× 350).

ON A PECULIAR FORM OF LIVER TUMOUR. By JULIUS DRESCHFELD, M.D., M.R.C.P., *Lecturer on Pathology at the Owens College, Manchester.* (PLATE XVI.)

THE patient, a man æt. 53, from whom the liver tumours which form the subject of the following brief description were derived, was an in-patient of the Manchester Infirmary, and suffered during life from all the symptoms of cancer of the liver. (The chief symptoms being: jaundice, which came on gradually without any great pain; the presence of an enlarged, hard, and nodulated liver; rapid emaciation; and, towards the termination of the disease, œdema and ascites.)

The *post-mortem* examination was made by my colleague, Dr James Ross, at that time pathologist to the Infirmary; and there were found no noteworthy changes in any organ but the liver. This was found to be very much enlarged, especially in its right lobe, and the seat of numerous small round tumours, varying in size from 2 to 6 centimeters in diameter. These tumours were found to occupy chiefly the right lobe, where they formed raised rounded masses, both on the upper and lower surface, while others were found scattered in the interior of the liver. In their outward appearance they differed from ordinary liver cancer, inasmuch as they were firmer on section, of greyish-yellow colour, and without central depressions. From the surrounding liver tissue they were separated by a distinct fibrous capsule.

The liver itself was of pale-yellowish appearance, firm, and moderately rich in blood; on section, the inter-lobular fibrous tissue was seen to be very much increased. The walls of the bile-ducts, which were distended with bile, were thickened, and the larger blood-vessels slightly dilated.

The gall-bladder was found filled with mucus, the cystic duct very much compressed by a large tumour nodule projecting from the lower surface of the liver. There were found also adhesions on the under surface of the liver, the result of recent perihepatitis.

The mucous membrane of the stomach was softened, and the

seat of numerous ecchymoses; ecchymotic spots were also found beneath the serous surface of the intestines and mesentery.

The pancreas was healthy; no cicatrix was visible in either stomach or intestines.

The thyroid gland was not enlarged. (This is especially mentioned, as the tumours, on superficial histological examination, resemble the metastatic glandular tumours of the thyroid described by Cohnheim.)

The histological examination of some of the tumour masses revealed an appearance different from that of any liver tumour hitherto described.

Sections of a tumour nodule, hardened in chromic acid, were first examined with a low power (fig. 1); the greater portion of the tumour (D, fig. 1), with the exception of the peripheric part, consisted of a fibro-cellular stroma, with numerous alveolar spaces of varying size and shape (*c*, *d*, *e*, fig. 1), some oval, some hour-glass-shaped, and some more nearly circular, while an alteration of the focus showed that several of the alveolar spaces communicated by narrow connecting links. Most of these alveoli were bounded by one or more rows of cells, while their contents, which had a very striking appearance, varied very much. In some the contents had quite a hyaline appearance, and seemed to be a uniform mass; in others the hyaline appearance was still marked, but the mass resembled more a mass of fused and degenerated cells, while in others, again, large cells, with well-developed nuclei, filled the interior. In many the contents had fallen out, and the lining cell-layer alone remained (*d*, fig. 1); in all, however, a clear zone of varying thickness separated the fused mass from the lining layer (*e*, fig. 1).

The peripheric part of the nodule nearest the part just described (*c*, fig. 1), though of more uniform appearance, showed smaller isolated patches of rows of cells, at once recognisable by the deeper staining and the larger size from the surrounding parts.

The outermost part of the nodule had a coarse fibrous appearance (B, fig. 1), the fibres being arranged concentrically, and passing gradually into the surrounding liver tissue (A, fig. 1), the changes of which could be more clearly made out on examination with a higher power.

The more minute examination of the several parts of the

nodule and liver with a high power, and with different staining agents (picro-carmine, logwood, Bismarck brown) showed the following points:—

Central Part of Tumour.—The stroma (*e*, fig. 2) consisted of fine fibres and a number of cellular elements (some identical with tissue corpuscles, having a long oval nucleus, others like leucocytes, others smaller and round), a number of nuclear bodies, and a few capillaries. In some places the stroma was very narrow, and formed only a thin wall between the epithelial lining of two adjacent alveoli; in others it was broader and richer in cells.

The alveoli consisted in most parts, as already stated, of a lining membrane and contents. The lining membrane, or rather layer, consisted of one or more rows of cells, which were closely united, and which varied in appearance, some being small and cubical, with a well-defined central nucleus; others larger, round, oval, or pear-shaped, with a larger, well-defined nucleus, filled with granular protoplasm. All the cells were of distinct epithelial character; some of the larger ones, however, resembled liver cells (*f*, fig. 2), and in some unstained preparations were found to be filled with yellow (bile) granules. The change from the smaller to the larger epithelial cells was in some spots very gradual, and could easily be made out (*a*, fig. 2). It was further remarked that where the alveolar contents had undergone the most marked degeneration to be immediately described, there only one or two rows of lining cells were found, whilst in those places where this degeneration was less marked, the boundary consisted of many rows of cells.

The alveolar contents consisted in many places of a hyaline material, which at first looked like an exudation, but which, on closer examination, was seen to be a fused mass of degenerated cells, larger than those forming the boundary, and with their nuclei still visible on staining (*g*, fig. 2). This fused mass did not give the amyloid reaction, nor did it clear on the addition of acetic acid or caustic potash solution, microscopically it resembled very much the vitreous changes seen in the giant-cells in old fibrous tubercles.

Peripheric Part.—The composition of this part varied in different spots. The more centrally situated parts had the structure

and appearance of true carcinoma, to wit, irregularly bounded alveolar spaces filled with epithelial elements (the cells varying in size from 9–12 μ, and possessing a large nucleus), and separated by a stroma consisting of fine fibres and small round and spindle cells. The parts nearest this periphery, on the other hand, showed a more uniform structure, and consisted of small cells and spindle cells. In several spots of the peripheric part (*b*, fig. 1), islets of cells were seen, which had quite the character of liver-cells, with granular contents, and large highly stained nuclei and double nuclei. The appearance of these islets of liver-cells differed most markedly from that of masses of degenerated liver-cells found outside the capsule which separated the tumour from the liver. There the rows of liver-cells formed flattened bands, with a more uniform protoplasm, and almost invisible nucleus, the bands tapering off at each end, and being surrounded and compressed by fibrous tissue. The islets of liver-like cells in the periphery of the tumour, on the other hand, with their large well stained nuclei and double nuclei, resembled much more a proliferating tissue, and were surrounded by the small cell growth already mentioned like an embryonic tissue. It was further remarked that at the periphery only of these islets did the liver-cells possess two nuclei; other changes, however, though often looked for, were not observed in these cells, &c.

The outermost zone of the tumour consisted of a fibrous capsule (B, fig. 1), as already stated, and this looked at under a high power was found to be made of several layers, the inner layers more cellular (spindle cells chiefly), the outer layers consisting of fully-formed fibrous tissue.

The *liver substance immediately outside* the capsule showed signs of compression and degeneration, and here the flattened bands of atrophied liver-cells already mentioned were principally found.

The *liver substance*, apart from the tumour, showed slight fatty infiltration of the peripheric part of the lobules. The interlobular spaces were widened, and contained an embryonic fibrous tissue, and marked proliferation of the biliary ducts (*a*, fig. 1); in fact, all the changes seen in incipient cirrhosis (chiefly monolobular.

The questions which naturally arise in connection with this tumour are two.

1. What is the nature of the tumour?
2. From which elements is it developed?

As regards the first of these questions, we have here evidently a primary multiple tumour of the liver (a most careful search revealed in no other organ a tumour or its remains, such as a cicatrix), which in its clinical features resembled cancer, and which in its histological structure also is more nearly allied to a carcinoma than to any other tumour form.

At a first glance, owing to the striking appearance of the alveolar lining of the epithelium, one might think of a lymphangioma. The facts, however, that the lining zone in many places consists of several and not of one row of cells, and that the contents of the alveoli are degenerated epithelial cells, and furthermore, the appearance of the peripheric part which evidently represents the younger and still growing part of the tumour, entirely shut out such a view.

Again, the patches of liver-cells in a state of proliferation in the outer part of the tumour suggest the idea of an adenoma of the liver, and the close relation between an adenoma and a carcinoma at first strengthens that theory; against it, however, may be cited several facts, the mention of two of which will suffice. 1st, The arrangement of the liver-cells in the tumour is different from that in a liver adenoma, where, as in all adenomata, the cells preserve to a great extent the arrangement which they have in the liver; and 2d, The character of the cells in the central part of the tumour, where the majority have a distinctly epithelial character.

To cancer of the liver, on the other hand, the tumour bears, histologically, the closest resemblance, and it is as a variety of cancer, in which some of the alveolar contents have undergone a peculiar vitreous degeneration, that it must be considered. Friedlander (Virchow's *Archiv*, 1877) describes a peculiar hyaline degeneration of the peripheric alveolar zone in some cancers, but I am not aware a degeneration of the central alveolar parts, similar to the one seen in this liver-tumour, has ever been described.[1]

[1] I have recently had the opportunity of showing some sections of the tumour to Professor v. Recklinghausen, who carefully examined it, and told me that only once had he seen a similar appearance, and that was also in a primary multiple tumour of the liver.

Except this peculiar degeneration, and especially in those parts of the tumour where this degeneration had not yet taken place, the tumour had all the characteristic appearances of cancer, namely, irregular alveolar spaces filled with epithelial cells, and separated by a more or less fibrous stroma. The close resemblance of some of the epithelial cells (in the central part of the tumour) to liver-cells (*b*, *d*, fig. 2) rather strengthens this view, for it is not unfrequently seen in cancer of the liver, and is especially dwelt upon by Perls (*Path. Anat.* p. 481).

As to the nature of the degeneration, I can only state that it did not give the amyloid reaction; it did not resemble colloid degeneration, but resembled more the vitreous changes seen in cells in catarrhal pneumonia and phthisis.

Coming now to the second point of our inquiry, as to the elements from which the tumour developed, we may dismiss from our inquiry at once the blood-vessels and lymphatics, as neither in the tumour itself nor in the liver-substance of which numerous sections were made, were there any appearances which could suggest such an origin. We are, therefore, limited to the biliary vessels and the liver-cells. The liver-substance away from the tumour certainly showed excessive proliferation of the biliary ducts; such a proliferation is, however, easily understood, if we consider that we have marked increase of the interalveolar fibrous tissue, and is, therefore, nothing more than the proliferation of the biliary ducts seen in both monolobular and multilobular cirrhosis. In the tumour itself no biliary ducts were found, and cylinder-cells were nowhere present. In the central part of the tumour we see, it is true, many cubical epithelial cells in the lining of the alveolar epithelium, but these are not seen near the periphery of the tumour, which represents the growing part, and where alone the development of the tumour could be studied with advantage and with any chance of success. It is, in fact, the study of this outer zone which leads one to think that the liver-cells formed the starting-point from which the cancer nodules developed. We see here islets of liver-cells which, from the appearance already described, are in an active state, and are not masses of degenerated liver-cells pushed aside and compressed by the tumour; we see also here an embryonic tissue immediately surrounding these liver-cells, and

though no direct passage of the liver-cells into these could be made out, in many places it was seen that those liver-cells nearest the embryonic mass were doubly nucleated; and, lastly, we have both in the peripheric zone and also in the central zone, where fully-formed cancer alveoli are noticed, the epithelial cells of these alveoli greatly resembling liver-cells—a condition which is also described by Perls (Virchow's *Archiv*, vol. lvi. p. 448) in liver-cancers, the origin of which he traced to the liver-cells. The presence of the fibrous capsule which separates the cancer-nodule from the surrounding liver tissue is by no means against this view of the development of the tumour and admits of the following explanation:—The irritation set up by the first start in the cancerous growth would be associated with an increase of the interlobular fibrous tissue; one or more lobules of the liver would thus become isolated from the rest of the liver tissue, and in those isolated nodules the cancer would develop further. In support of this view I may refer to the observations of Perls (*loc. cit.* p. 452) and those of Fetzer (*Beitrage zur Histologie des Leber-Krebses*, Tübingen, 1868), where in several cases of cancer of the liver, the origin of which was traced to the liver-cells, similar fibrous capsules surrounding the tumour-nodules are described. If we further assume that the incipient cirrhosis found in this liver is not due to the biliary obstruction, but was antecedent to the formation of the cancer (and I have only found the monolobular cirrhosis of Charcot and Gombault in cases of long-standing biliary obstruction), the explanation given above is still more feasible.

The examination of a number of cancers of the liver, which I have lately had an opportunity of making, has shown me that their development from liver-cells is by no means common, and I hope shortly to recur to this subject. I have here merely wished to record the existence of this peculiar tumour and its development, and have for this reason avoided all bibliographical references.

Explanation of Plate XVI.

Fig. 1 (low power).—*A*, liver-tissue; *B*, fibrous capsule of tumour; *C*, peripheric part of tumour; *D*, central part of tumour; *a*, proliferation of biliary ducts; *b*, islets of liver-cells in tumour; *c*, alveoli, with lining epithelial layer, and filled with epithelial cells; *d*, alveolus, in which the contents have fallen out, while lining epithelium has remained; *e*, clear space between fused mass and lining layer; *f*, stroma between the alveoli.

Fig. 2 (high power).—*a*, epithelial lining, the cells being cubical; *b*, epithelial lining (the cells have more the character of liver-cells); *c*, central fused mass in alveolus; *d*, alveoli where cells have not undergone degeneration; *e*, stroma; *f*, the epithelial lining consists of several rows,—some of the cells resemble liver-cells; *g*, fused mass, consisting of degenerated cells.

CASE OF CEREBELLAR TUMOUR (*PSAMMO-SARCOMA*).

By JULIUS DRESCHFELD, M.D., M.R.C.P., *Lecturer on Pathology, Owens College, Senior Assistant Physician, Royal Infirmary, Manchester.* (PLATE XVII.)

JOHN H., æt. 21, first came under my observation as an out-patient in September 1877. He was stated to have always had good health and to have had no illness, excepting an attack of fever seven years ago, which laid him up for fourteen weeks, but from which he quite recovered; had always been of temperate habits, had gonorrhœa but not syphilis. Some weeks before admission he began to suffer from headache, which became so severe and persistent that he was obliged to give up his work as a labourer a fortnight before admission, the headache (chiefly occipital) was not accompanied by any other symptoms, troubled him mostly in the day, was not increased after meals, and not accompanied by either nausea or vomiting, and the patient could not assign any cause for it. Bromide of potassium was prescribed, but without any benefit. After the patient had been under treatment for a fortnight, an ophthalmoscopic examination of the eyes showed marked optic neuritis in both eyes, though the acuteness of vision was normal. Beyond the optic neuritis and the persistent headache, no other symptoms could at that time be made out; the presence of the optic neuritis, however, made it already highly probable that the patient was suffering from a coarse cerebral lesion, though it was impossible to localise it. In January 1878 the patient complained for the first time of giddiness and occasional staggering when walking quickly or trying to turn himself round; on examination, it was found that the patient, with his eyes shut, could not stand or walk without staggering, and when turning round sharply, he staggered a good deal whether the eyes were shut or open. The staggering increased, and the man was made a home-patient, under the charge of Mr Hunt. One morning (Feb. 25, 1878) when trying to get up from bed he fell back, owing to the excessive vertigo and stagger-

ing, and from that day forward he was never able to walk without assistance. Soon after he was seized with vomiting (not preceded by nausea), and this continued throughout the greater portion of his illness. With the advent of these graver symptoms, he at last consented to be made an in-patient, and was admitted into the Infirmary on March 4, 1878. The progress of the case will be best seen from the following brief extracts from the notes taken by my clinical clerks, Messrs A. E. Chambers and J. K. Milne:—

Condition on admission (March 4).—Patient of middle stature; slightly emaciated; of sallow complexion; expression of face dull; skin dry; extremities, especially the lower, feel cold to the touch.

Antero-posterior diameter of head rather large; no nodes, ulcers, or eruptions.

Complains of severe occipital and frontal headache; no affection of any of the cerebral nerves or special sense-organs, except marked optic neuritis in both eyes, with nearly normal vision; no terniapia.

Chest organs normal; pulse slow and regular.

Tongue clear; appetite good; vomiting of food occurs once or twice daily; marked constipation; abdomen retracted; abdominal viscera normal in their relations.

Urine, sp. gr. 1017, slightly alkaline, no albumen or sugar; slight sediment containing triple phosphates.

Upper extremities perfectly normal as regards mobility, sensibility, and electric reactions.

Lower extremities.—When in recumbent posture is able to perform all movements well, whether the eyes are shut or open; the muscular power in both lower extremities very considerable; there is neither anæsthesia, nor analgesia, nor affection of the muscular sense. When sitting up in bed there is no vertigo. When attempting to stand erect by himself he falls forward, and likewise when attempting to walk; when supported on each side can walk, and raises both feet well from the ground, but staggers from side to side. The unsteady gait still more pronounced with the eyes shut.

Diagnosis.—Cerebellar tumour, affecting chiefly the superior vermiform process.

The symptoms remained the same till the beginning of May, when patient had an epileptic attack, which was followed by many more in the progress of the disease. These attacks, several of which were seen by myself and Mr Milne, were much more of tetanic character than ordinary epileptic seizures. With or without loss of consciousness, the four extremities became suddenly powerfully contracted; the arms flexed, the legs extended, and the head forcibly drawn back. This state was followed by slight clonic contractions of very short duration, and to these succeeded a state of complete exhaustion which lasted for several hours.

The condition of the patient remained stationary for some time; the constipation, however, became very obstinate, and only yielded to the administration of croton oil (two to three drops); the appetite began to fail, and the patient became much weaker and much more emaciated. . . . During June and July the patient's condition grew worse; the lower extremities were distinctly paretic, and there supervened incontinence of urine, in consequence of which the patient was transferred to the Manchester Workhouse, where he remained under the charge of Mr Jackson, assistant medical officer. The patient sank slowly but gradually; he became completely paraplegic; the optic neuritis went on to atrophy, and he became quite blind; deafness supervened, and he died on December 9, 1878, his intelligence remaining intact up to the very last.

The *post-mortem* was made by Mr Jackson on December 10 in my presence. The only noteworthy changes were found in the brain. The bones of the skull and the membranes of the brain were healthy; the sinuses contained a large quantity of blood. The fluid in the subarachnoid space was found increased. The brain was easily removed, and there was found on the upper surface of the cerebellum a large, firm, nodulated, well circumscribed tumour pressing forward between the hemispheres (which were pushed aside), and partly overlying the peduncles, which were found very much flattened. On a more careful examination, it was seen that the tumour had sprung from, and entirely replaced the superior vermiform process; it measured nearly 2½ inches in length, and at its base 1½ inch in thickness; the lateral lobes of the cerebellum, beyond slight flattening, showed no other changes; the brain also, beyond the compression of the occipital

lobes and the marked flattening of the peduncles, showed nothing abnormal either on its surface or in the cerebral ganglia and medullary substance, while the lateral ventricles contained a large amount of serum. (Fig. 1 is an exact representation of the tumour, kindly drawn for me by my friend Dr Young; it, however, represents the tumour in a much more vertical position than it had when examined *in situ* as stated above. This vertical position it assumed immediately after the separation of the hemispheres, as if suddenly relieved of some force causing it to project forward. During life, the tumour, following the direction of least resistance, grew forward, and thus caused the flattening of the peduncles, which is well represented in the drawing.)

The histological examination of the tumour revealed some very interesting points, but before describing these it may not be out of place to consider those clinical features which bear a direct relation to cerebral localisation. The points to which I should like to draw attention are briefly these:—

1. The possibility of an accurate diagnosis being formulated at a very early stage of the disease, owing to the marked character of the symptoms (occipital headache, optic neuritis, staggering without paralysis).

2. The position of the tumour.—From a very careful analysis of numerous cases, Nothnagel (*Berl. Klinische Wochenschr.* 1878, No. 15, and *Topische Diagnose der Gehirnkrankheiten*, pp. 4–6) makes the staggering in cerebellar disease dependent chiefly on lesions of the superior vermiform process. The above case strongly supports that view.

3. The tetanic nature of the convulsions, which was so well expressed and so peculiar as to arrest our attention, derives great interest from the very recent observations of Hughlings Jackson (*Brit. Med. Journal*, Feb. 7, 1880), according to which rigidity of groups of muscles and tetanic-like paroxysms form important localising symptoms in cerebellar disease. Since the publication of Hughlings Jackson's interesting paper, a case by Dr Bacon (*Brit. Med. Jour.* Feb. 21, 1880) of cerebellar tumour has been reported, in which such tetanic seizures were well marked; and I have at present a patient, who, besides the ordinary symptoms of cerebellar disease, has persistent retraction of the head owing to rigidity of the muscles of the neck. Again,

stiffness of limbs has been found to follow ligature of both vertebrals in animals (Cooper, Schiff).

4. All the other symptoms described are common to all cerebral tumours, and cannot be made use of for localising purposes. The paraplegia observed towards the close of life was evidently due to pressure of the tumour on the peduncles. The minute examination of the tumour showed some peculiar points interesting pathologically.

On section the tumour was found to be firm, whitish in colour, uniform and rich in blood-vessels, which ramified throughout the tumour. Some portion of the tumour had quite a gritty feel, and made the knife grate on cutting; these parts had a more opaque granular appearance.

Histologically the tumour was found to be a spindle-celled sarcoma; the cells (very small, tapering off at each end, containing a long rod-like nucleus, and but little protoplasm besides this) were arranged in rows, running in all directions, some more transverse, others more vertical; the cells were very much flattened, and their exact nature could only be made out by teazing. There was hardly any intercellular substance; the blood-vessels, however, were found numerously distributed throughout the whole tumour, and were of varying sizes; their walls consisted of spindle-cells of exactly the same shape as those making up the tumour, and the walls of the larger ones differed from those of the smaller ones merely in the thickness of the cell layers (fig. 2, *a*); the parts of the tumour adjacent to the blood-vessels had the cells arranged in rows which ran parallel to these blood channels. The vessels were often found empty, in some places still filled with blood-corpuscles; in no part of the tumour, however, was there seen any calcification of the contents.

In many parts of the tumour the spindle-cells were arranged in concentric layers forming nests (Gowers described these tumours, therefore, as nested sarcomata), in the centre of which the cells had lost their cell character and appeared as mere nuclei (fig. 4, *b*). In other portions of the tumour the above-described nests, though still surrounded by spindle-cells, had a more uniform, colloid appearance, but, on using a staining agent, the remains of the cell-nuclei could still be made out, and the

nest had thus the appearance as if made up of lamellæ (fig 3, *c*; fig. 4, *c*); other nests showed in the central part minute calcareous granules. On examining now the parts which felt gritty, which were mostly the deeper situated parts of the tumour, the same structure was seen, with the exception that the nests now were altogether calcareous. After decalcifying such portions of the tumour there could still be rendered visible, on the application of a staining agent, the remains of cell-nuclei in the interior of the nest; showing thus very clearly that the only change in this part of the tumour consisted in a calcareous degeneration of the cells constituting the nests. Moreover, in many nests, some of the outer cell layers were still intact, while the central part had already undergone calcareous degeneration. The rest of the structure in these calcareous portions resembled the other portions in every particular; the calcareous bodies were surrounded by closely-packed spindle-cells; the blood-vessels, smaller and more sparingly distributed, had the same embryonic appearance as in the other portion of the tumour first described. In no part of the tumour could there be seen a calcareous deposit in the lumen of the blood-vessel or a calcareous degeneration of its walls. Looking at the embryonic state of the blood-vessels one might at first be inclined to take the psammomum nests for transverse sections of such vessels; the presence of the cell remains, however, in these nests, the gradual transition of the nests filled with perfect cells into the colloid degenerated and laminated nests, and, lastly, the appearance of separate minute calcareous particles in the nests are quite opposed to such a view. Besides, in no part of the tumour could there be seen any calcareous cylinders corresponding to longitudinal sections of calcareous degenerated blood-vessels, which one would most certainly expect to find in a tumour where the calcareous masses and the blood-vessels were so abundant.

From this histological description, it is evident that while some portions of the tumour are spindle-celled sarcoma, others are the nested sarcoma of Gowers, and others, again, correspond in every sense to the psammomum of Virchow. It is further evident that these different appearances are merely due to the concentric arrangement of the spindle-cells and their subse-

quent calcareous degeneration. (I cannot say whether in all cases the nests before becoming a true psammomum body had at first to undergo the peculiar colloid degeneration.) If we now look at the literature of the subject, we must come to the conclusion that the tumour described originally by Virchow as psammomum is only a generic term, and represents nothing more than a calcareous deposit of peculiar form in tumours of widely different structure. Nor are such tumours entirely confined to the brain and its membrane as was at first thought, for they have been described in orbital (Neumann), in mammary (Ackermann), and in ovarian tumours (Spiegelberg, Marchand, Olshausen, Flaischlen).

If we briefly summarise their modes of development we find:—1. Development from cells, and here they may develop from spindle-cells (the above case, Steudner), or from endothelial cells (Robin, Neumann, Perls, Golgi, Lancereaux, who calls these tumours endotheliomata); from the epithelial cells of carcinomatous tumours (Ackermann, Flaischlen). 2. Calcification of the contents of the blood-vessels; analogous to the formation of phleboliths (Cornil and Ranvier, Arnold), giving rise to the angiolithic sarcoma. 3. Calcification of the walls of the blood-vessel (Arnold, Schüppel).

Seeing thus that the psammomum bodies occur in so many different tumours, and that they may develop from many different elements, I think it will be well to speak of it merely as a degeneration, and hence I have called the tumour a psammo-sarcoma. Flaischlen in his recent paper adopts a similar course, and describes a carcinomatous tumour of the ovary in which a number of psammomum bodies occurred (which he could trace to a calcareous degeneration of a number of epithelial cells) as a psammo-carcinoma.

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POST-MORTEM IN A CASE OF EXTREME OBESITY.

By THOMAS OLIVER, M.B., *Physician to the Newcastle-upon-Tyne Infirmary.*

As showing the enlargement the various organs of the body may undergo in cases where there is a tendency to the general deposition of fat, the following notes may prove of interest to some readers.

On the morning of the 9th March 1877, while engaged in private practice in Preston, I received a hurried message to go at once and see a man who had been found dead in bed. When I reached the house I found a huge man lying dead. He had evidently been dead a few hours. As he had gone to bed on the previous evening apparently well, I acquainted his medical man with the circumstances of the case, and at his request made a *post-mortem* examination for him on the following day.

The subject of these remarks—W. S., aged 50 years—had previously been an overlooker in one of the cotton factories of the town, but owing to his increasing bulk he had been obliged to give up his situation, and for a few years before his death he had followed no occupation whatever. He was not a tall man (I should think about 5 feet 4 inches), but was extremely fat. He was very lazy; everything in the shape of movement was a trouble to him—so much so that for months before his death he seldom rose from his chair, unless it was at times, and that very occasionally, to stand at the open door of his house. His daughter and his sister-in-law informed me that a year before his death he weighed 30 st. 6 lbs. He was a perfect glutton, and was, it would seem, a heavy tax upon his daughter, who worked hard to support him. On the evening before his death he ate six eggs and two tea-cakes; and on one occasion—four months before his death—when Mr Foulis (Dr Smith's assistant) was attending him for bronchitis, he found his patient demolishing two loaves of bread, two bottles of porter, half-a-dozen onions, and half a pound of butter. It was the usual thing when Mr Foulis called to find his patient asleep on his chair, for he could not be got to bed. For months before his death he had not worn stockings; none could be got large enough for him.

Autopsy twenty-six hours after my visit to the house—a huge cadaver—very livid, almost black—rigor mortis well developed.

On making the customary incision from episternum to pubis the subcutaneous fat is noticed to be markedly increased. Before reaching the surface of the sternum I had to cut through quite two inches of fat. Towards the lower part of abdomen the adipose tissue between the rectus abdominis and the skin is nearly three inches in thickness; the rectus muscle itself is almost as thin as paper.

Chest.—The pericardium is coated with a thick layer of soft oily fat about half an inch in thickness. On opening the sac it is found to contain about an ounce and a half of serum.

The heart is very much enlarged—resembling in appearance that of an ox. The heart itself is slightly displaced; its base is a little lower down than usual, and more to the right side than normal. The whole of the right side of the heart is lying upon the diaphragm. The heart on its removal, and when emptied of the dark fluid blood which it contained, weighs 2 lbs. 6¼ oz. It is covered with a deep layer of fat. The aortic and pulmonic valves are healthy; the mitral and tricuspid, as far as could be ascertained by the finger inserted into the auricles, are also healthy. The aorta and pulmonary artery present here and there a few small atheromatous patches. I preferred keeping the heart intact, as it was a good example of simple hypertrophy—hypertrophy without the co-existence of valvular disease, and I ultimately sent it to the museum at St Bartholomew's Hospital.

Lungs.—The left lung is engorged with blood; its lower lobe is slightly œdematous; the upper lobe is emphysematous. The bronchial mucous membrane is hyperæmic. The right lung is also engorged.

Abdomen.—Fat is freely distributed through the omentum, and the appendices epiploicæ are particularly large. The liver is increased in size, weighing 6 lbs. 10¾ oz. It contains too much dark blood. On scraping a section of it the surface presented here and there small yellow foci—small areas of hepatic tissue deeply stained with biliary pigment. Capsule of liver normal. Gall-bladder contains fluid bile.

The spleen is enlarged and hard; it is dark in colour, and weighs 25 oz. It cuts like a cake, the sections falling asunder

like slices of soap. Its tissue is very firm, and easily breaks down on pressure.

The kidneys are with difficulty caught hold of, for they are deeply embedded in a thick mass of fat nearly an inch and a half in thickness. The two kidneys weigh together 25 oz. Both are deeply engorged with blood. Their capsule is removed with ease. Microscopical examination afterwards showed that they had undergone extreme fatty degeneration; the renal cells and stroma had a very oily aspect.

The venous system in general is engorged with dark fluid blood. Although the patient died yesterday morning, and the body has been lying in a cold room ever since, all the internal organs are warm.

The friends refused to grant me permission to examine the head.

All the organs of the body were enlarged in this case. As the result of increased functional activity, they had all undergone simple hypertrophy. The heart, for instance—taking the average weight, as given by Reid, as 11 oz.—was enlarged nearly three and a half times its normal size. The enlargement was in all probability co-incident with the enlargement of other organs, and was necessitated by an increase in the circuit of the circulation caused by the deposition of fat. Had the hypertrophy been confined to the left side of the heart the enlargement might have been one possibly consequent upon the destruction of the secreting cells of the kidney, but it was too general to have such a causation. There are many larger and heavier hearts than the one I have just recorded, but in the most if not all of them there has been concurrent disease—either endocardial changes, aneurism, or Bright's disease. Within the last few days we have received at the College of Medicine here a large heart from Carlisle, which on its removal from the body weighed nearly 50 oz., but its valves are diseased. For a simple hypertrophied heart—for a heart which has increased in size in accordance with a general process of enlargement throughout the body—38 oz. is a good weight. In its weight, however, the heart in this case has maintained as nearly as possible that proportion to the body which Reid[1] mentions, viz., 1 to 169.

[1] Quain's *Anatomy*, vol. i. p. 321.

ON THE HEAD OF THE LOBSTER. By Professor JOHN YOUNG, *University of Glasgow.* (PLATE XVIII.)

ON the tergal surface of the carapace of the Lobster an irregular area is marked off by a straight transverse groove and a posterior crescentic one, whose convexity points backwards. The anterior straight groove (fig. 1, *e*) is the deeper, and has a corresponding ridge which projects into the thoracic cavity. The posterior groove (fig. 1, *f*) is double and very shallow, and has no corresponding internal ridge; it is the direct continuation backwards and upwards of the lateral grooves. These consist of an oblique lateral portion which passes downwards to a point corresponding to the articulation of the mandible (fig. 1, *d*), and then divides into two, a short groove (*b*) which approaches the margin of the branchiostegite opposite the interval between the maxillipeds and chelæ; and a large one (*a*) which runs forward, turning up slightly at its end, to the broad preoral sternum. At the point of divergence (*d*) of these two last, an internal convex eminence fits into a notch of the mandibular (?) epimeron, and this notch is represented on the sternal aspect of the epimeron by another convex eminence to which is adapted the cup-shaped base of the mandible. In transverse section (fig. 5) the pleural, epimeral, and mandibular balls and sockets are closely parallel. The anterior part of the cervical groove (fig. 1, *a*) answers anatomically to the posterior limit of the three prestomial sterna, ocular, antennular, antennary: the middle or descending groove (*b*) answers to the posterior limit of the maxillipeds, while the posterior oblique groove *l–d*, with its corresponding internal ridge answers to the anterior boundary of the branchial chamber, and in young subjects is conspicuously prolonged backwards on either side of the cardiac region by a groove (*g*) which marks the upper limits of the branchial chamber. The straight transverse groove which joins the oblique lateral one nearly at right angles, *l* marks off that region of the carapace which seems specially related to the prestomial somites. So far, then, as the anatomy of the adult is concerned, the cephalic region does not include the mandibular and maxillary somites; these, with the

maxillipeds, having the posterior limit which Milne-Edwards assigned to the head. It may be mentioned in passing that the second maxilla is articulated behind the first in front of the first piece of the thoracic endoskeleton. The pleural area corresponding to these poststomial somites is wanting, and the tergal area is reduced to the irregular space above mentioned. Claus has already referred the mandibles not to the third appendage of the nauplius, but to the surface posterior and internal to that appendage. In the larvæ of a macrurous crustacean caught in the Clyde with the surface-net, I found the mandibular thickening not united with the third appendage but distinctly posterior to it and nearer the middle line. It is therefore probable that the mandible, which is in several respects unlike the other appendages, is merely a more complete calcification of the lateral oral margin than is seen in the labrum, and that the third appendage of the nauplius becomes united with it in process of growth, and survives as the mandibular palp whose nervous supply comes from the supra-œsophageal ganglion while the mandible is supplied from the first ventral ganglion. This separation of a prestomial region in the Lobster and in the Crayfish is in harmony with the anatomy of the Annelids, in which likewise a prestomial region exists with an identical nervous supply, that is one derived from the supra-œsophageal ganglion. In the Stomapoda, the first and second somites are free, and the antennary lodges the stomach, while the Pontellidæ present a still clearer case of a prestomial or cephalic segment.

The points to which I wish to draw attention are (1) that the "cephalic groove" is in reality made up of two parts, (*a*) the fold which marks off the prestomial segment and starts from the antennary sternum, (*b*) the fold which starts behind the maxillipeds and joins the preceding opposite the mandibular articulation; (2) that the lateral surfaces answering to this second group of appendages are obsolete, the tergal being reduced to small space; (3) that the mandible is by its development on a different footing from the other appendages, while by its anatomy it is closely similar to the hollow epistoma; (4) that the nervous supply of the prestomial segment, including the mandibular palp, is derived from the supraœsophageal ganglion; (5) that the sense organs,

eyes, antennules, antennæ, with the sense sacs lodged in the bases of the latter, are confined to a highly specialised region; (6) that this division is not without parallel in other crustaceans, and that, in fact, the adult Lobster retains more of the primitive relation than is found among the Entomostraca for example. This division of the lobster's body is not at variance with the now almost forgotten view that the supraœsophageal ganglion is the last survivor of a tergal chain which with the tergal vessels answered to the sternal ganglia and vessels. So long as the relations of the procephalic lobes are uncertain, so long as it is possible that they are terga, which have been superseded, so to speak, by the more rapid calcification of the carapace and development of the carapace, the anatomy of the Stomapoda is not adverse to this view.

Explanation of Plate XVIII.

Fig. 1. Lateral view showing "cervical grove," and branchial chamber, *a*, *b*, *l–d*, anterior, middle, and lateral grooves; *e*, *f*, anterior and posterior tergal grooves; *g*, upper, *k*, anterior limits of branchial chamber; *h*, lining membrane of branchi ostegite; *i*, branchia; *p.c.l.*, procephalic lobes.

Fig. 2. Under surface, showing preoral sternum, *c*; epistoma, *e*, with two calcified plates at its base; and the articular spaces for Mx, Mx_1, Mx_2, Mxp, 1, 2, 3, Chelæ. The space for Mx_2 is behind the maxillary sternum and the first piece of the thoracic endoskeleton; *b*, corresponds to *b* in figs. 1 and 5.

Fig. 3. Upper view, carapace partly removed; *b*, *e*, *f*, *g*, *l*, *p.c.l*, as in fig. 1.

Fig. 4. Under view of antennule, antenna, preoral sternum, *c*; epistoma, *ep*; and mandible; *a*, articular surface answering to *a* in fig. 5, and fitting on *b* in fig. 2, 3, 5; *a*, articular surface fitting on a_1 in fig. 3.

Fig. 5. Transverse horizontal section: *a* articular cup of Mx; *b*, ball on epimeron; *d*, pit of "cervical groove." (*The specimen got dry and warped before the drawings were executed.*)

NEW ABNORMALITIES OF THE ARTERIES OF THE UPPER EXTREMITY. By W. STEPHENSON RICHMOND, *Student of Medicine, St Bartholomew's Hospital.* (PLATE XIX).

I HAVE just dissected an arm in which the arteries had such extreme abnormalities that they are, perhaps, worth recording on account of their rarity.

The brachial artery gave off, a little higher than its middle, a large branch (fig. 1, *a*), which pierced the brachial aponeurosis and ran superficially along the inner side of the upper and fore arms to the palm of the hand. It lay in its entire course in the superficial fascia, and gave off no branch before reaching the palm. It passed over the annular ligament on the outer side of the pisiform-bone and entered beneath the palmar fascia, where it terminated by dividing into a superficial and a deep branch (fig. 1, *c*), the former of which joined the superficialis volæ branch of the radial and formed the superficial arch, whilst the latter represented the profunda ulnaris and joined the deep arch. The superficial arch first gave a branch to the inner side of the little finger (fig. 1, *d*), it then gave off three other branches (*e*, *f*, *g*), which anastomosed with the digital arteries of the deep arch.

The brachial artery divided in the usual way in the triangular space at the bend of the elbow into two branches of equal size—one forming the radial artery, which was quite normal, the other forming what should be the ulnar, but in this case an artery, only two inches in length, which descended on the inner side of the tendon of the biceps, and after giving off the ulnar recurrent and common interosseous, terminated in a number of small arteries, which entered the flexor muscles on the inner side (fig. 1, *b*).

The deep palmar arch presented, perhaps, stranger peculiarities. The radial artery entered the palm as usual between the first and second metacarpals and gave off the arteria magna pollicis. When it reached the inner side of the second metacarpal bone it bifurcated, or rather gave off a large branch equal in size to

its continuation (fig. 2, *g*). This branch proceeded obliquely towards the base of the first phalanx of the middle finger, where it, in its turn, divided into two branches—one supplying the place of the radialis indicis (fig. 2, *b*), and giving off an anastomosing branch for the inner side of the index finger (fig. 2, *k*), the other giving digital branches to the middle and ring fingers (*l*, *m*, *n*). Returning to the arch: a small perforating branch (*b*) was given off at the third interosseous space, which passed to the back of the hand and anastomosed with the third dorsal interosseous; and another branch (fig. 2, *c*) was given off at the fourth interosseous space which ascended towards the base of the first phalanx of the ring finger, where it divided into three branches. The first (fig. 2, *d*) anastomosing with the artery of the outer side of the ring finger, and thus completing a third arch. The second (fig. 2, *e*) running up the inner side of the same finger, and the third (fig. 2, *f*) running up the contiguous side of the little finger. The arch divided and met again before joining the profunda ulnaris. Through the loop thus formed passed the deep palmar nerve.[1]

Such a division and distribution of the main arteries of the arm I believe to be entirely new. As far as I can ascertain this is the only case recorded where a branch from the brachial runs down the ulnar side of the arm, and has the distribution of the ulnar in the palm, while another distinct artery has the distribution of the ulnar in the forearm.

[1] See Professor Turner's "Notes on the Dissection of a Negro" (this *Journal*, xiii. p. 385) for an account of a loop-like arrangement of the deep palmar arch.

ABNORMAL ARRANGEMENT OF THE THYROID ARTERIES. By R. J. ANDERSON, M.D., *Demonstrator of Anatomy, Queen's College, Belfast.* (PLATE XX.).

I. THE INFERIOR THYROID ARTERY.

In a Male Subject.—The right superior thyroid arises from the external carotid near its origin, and divides into two branches —inner and outer.

The subclavian artery gives off the following branches:— The vertebral which has the usual position. The internal mammary is normal in position and relations. The suprascapular arises from the first stage of the subclavian as a separate branch. The posterior scapular arises from the first stage, and passes behind the anterior scalenus, and between two cords of the brachial plexus. The superficial cervical arises from the first stage close to the origin of the inferior thyroid.

The inferior thyroid is derived from the first stage of the subclavian artery; it arches upwards and inwards, gives off the ascending cervical at a distance of one inch from its origin, and immediately after divides into two branches, superior and inferior. The former passes upwards and inwards behind the sheath of the common carotid and the sympathetic cord, and beneath the right lobe of the thyroid gland, and is distributed to the posterior, lower, and outer part of that lobe. The latter passes in front of the carotid at a lower level than the superior branch, and after a more prolonged course supplies the inner and lower part of the right lobe of the thyroid body, and gives branches to the anterior surface. The above arrangement is easily accounted for by supposing the inferior thyroid to divide nearer to its origin than usual, and the lower branch to pass in front of the carotid artery in place of behind it.

In twelve subjects examined the inferior thyroid arose in one case as a separate branch from the subclavian, in one case from a trunk common to it and the transverse cervical, and in the remaining cases from the thyroid axis. In these cases the inferior thyroid had one of the following arrangements:—it

passed upwards and inwards behind the common carotid as a single trunk, and divided beneath the thyroid body into two or more branches; or, secondly, it passed as a single trunk behind the common carotid, and divided between that artery and the thyroid body into two vessels, one of which (the superior) passed beneath the thyroid body and supplied the posterior and lateral part of the right lobe, and the other (inferior) passed inwards below the thyroid body, and distributed branches to the lower mesial part of the gland, or the inferior thyroid divided outside or behind the carotid, and the two branches passing behind the sheath were distributed as in the last case. In four cases the inferior thyroid divided internal to the carotid. In three cases it divided outside (two), or beneath the common carotid artery (one). In the remaining cases the artery remained as a single trunk, and passed as such beneath the thyroid gland.

The condition of the inferior thyroid artery here noted differs from the third variety in that the second branch passed in front of the common carotid.

An instance is on record when two inferior thyroid arteries were present, one of which passed in front of the common carotid.[1] This case might be considered a variety of the foregoing, in which the division was transferred to the origin of the artery. The other arteries, it will be seen, arose as independent branches from the subclavian in place of the thyroid axis. A change in the relative position of the parts might be supposed to account for them, as well as other arterial abnormalities in connection with the thyroid gland.

An arterial thyroidea ima is known to arise occasionally from the inferior thyroid artery (Gruber), and from the supra scapular (Nuhn and Gruber).[2] The instances recorded of the latter variety resemble closely the instance above given, as the arteria thyroidea in these cases passed in front of the common carotid.

II. The Superior Thyroid Artery.

In a Female Subject.—The left common carotid divides opposite the upper border of the thyroid cartilage. The external carotid gives off the following branches:—The occipital at

[1] Quain, *Arteries*, p. 170.
[2] Henle, *Handbuch der Gefässlehre*, p. 265.

a distance of three-quarters of an inch from its origin. The ascending pharyngeal arises from the posterior surface close to the preceding. The posterior auricular arises at a distance of one inch and a-half from the origin of the carotid. A lingual-facial trunk which arises from the carotid at the same distance from the origin as the occipital artery, and divides one quarter of an inch from the carotid into the lingual and facial branches.

The superior thyroid, which is single, and arises from the common carotid near its termination, passes downwards and inwards, and divides opposite the upper border of the thyroid cartilage into two branches, which are distributed to the inner and outer parts of the anterior surface of the thyroid body. The superior laryngeal branch is given off by this artery at a distance of one inch from its origin, and passes inwards to the thyro-hyoid membrane.

The inferior thyroid of the left side arises from the thyroid axis, and divides into two branches at a distance of two inches from its origin. The upper passes behind the left lobe, and is distributed to its posterior surface. The lower is distributed to the lower and inner part of the left lobe.

The right external carotid gives off the following branches: —The occipital artery arises in common with the sterno-mastoid artery. Both arteries hook round the hypoglossal nerve. The ascending pharyngeal arises from the posterior part of the external carotid close to the occipital. The lingual and facial arteries have the usual disposition. Two superior thyroids arise from the internal part of the external carotid. The upper superior thyroid, which is the larger, passes downwards and inwards, and divides into two branches near the upper border of the thyroid cartilage; of these the inner passes beneath the sterno-hyoid and over the thyro-hyoid, then turns downwards over the thyroid body, and distributes branches to the inner part of the anterior surface and the isthmus, and gives off a crico-thyroid branch at the lower border of the thyroid cartilage. The outer passes beneath the sterno-thyroid, and crosses the right lobe obliquely from above downwards and inwards, and distributes branches to the anterior surface, external to the preceding, reaching as far as the lower third of the gland. A hyoid branch is given off by the upper superior

thyroid, which is directed to the lower border of the hyoid bone. The lower superior thyroid artery courses downwards and inwards to the thyroid body, beneath which it passes, and is distributed to the posterior surface of the right lobe.

The inferior thyroid artery of the right side divides at a distance of one inch and a quarter from its origin into two branches. The upper passes beneath the right lobe, and is distributed to the posterior surface. The lower passes below the right lobe of the thyroid body, and is distributed to the lower and inner part of the gland.

Cases in which two superior thyroid arteries are present must, as Gruber points out, be distinguished from those cases in which one or more arteries, commonly branches of the superior thyroid, are transferred to another arterial trunk. Thus, the superior laryngeal is known to arise from the external carotid and common carotid, and even from the lingual and ascending pharyngeal, and the muscular branches have been seen to arise from an independent trunk whilst the superior thyroid divided into two branches, laryngeal and thyroid (Meckel).[1]

In 292 cases Quain found three cases of double superior thyroid arteries, in two of these the superior laryngeal arose as a separate branch from the external carotid.[2] In the case figured by Tiedemann, the two thyroid arteries came from the external carotid, the lower gave off the dorsalis lingual, the upper the superior laryngeal and sterno-mastoid branch.[3] In Lauth's case, also referred to by Gruber, the upper thyroid gave off the superior laryngeal. In Gruber's case the upper, which he calls superior thyroid No. II., was derived from the lingual, the lower, called superior thyroid No. I., was derived from the external carotid.

The instance here given differs, therefore, from the cases above referred to, in that the lower thyroid artery gives off the laryngeal which, in the cases noted by Quain, Tiedemann, and Lauth, arose either as a separated artery from the external carotid or as a branch from the inferior. It differs, on the other hand, from Gruber's case, in that the superior artery was, like the inferior, derived from the external carotid.

[1] Gruber, *Beobachtungen aus der menschlichen und vergleichenden Anatomie*, 2 Heft.

[2] Quain, *Arteries*, p. 106.

[3] Tiedemann, *Tabula*, vii. fig. 1.

A VARIETY OF THE MYLOPHARYNGEUS AND OTHER UNUSUAL MUSCULAR ABNORMALITIES.

By R. J. ANDERSON, M.D., *Demonstrator of Anatomy, Queen's College, Belfast.*

In a Male Subject, on the left side of the body.—The portions of the *superior constrictor* attached to the internal pterygoid plate, the pterygo-maxillary ligament (in great part) and the mouth and tongue are normal in their attachments. The part arising from the mylohyoid ridge (for the extent of one quarter of an inch), and from the maxillary extremity of the pterygo-maxillary ligament (for half an inch) form a band three-quarters of an inch wide, which passes downwards and backwards for one and a half inch. It is at first blended with the superior constrictor, but separates from it as a distinct band at the place of entrance of the stylo-pharyngeus, and immediately divides into two parts. One of these, the larger, passes downwards and backwards, superficial to the middle constrictor; at first, interlacing with this muscle and afterwards becoming continuous with its fibres. The anterior longer and narrower than the preceding, but becoming broad at its insertion, is attached to the posterior border of the thyroid cartilage in a line with, but above the attachment of, the stylo-pharyngeus to the posterior border. The extent of the attachment of the muscle to the thyroid cartilage is three-quarters of an inch.

In a Male Subject, in the right upper extremity.—The *extensor carpi radialis longior* arises from the ridge above the external condyle and terminates in three tendons below the middle of the forearm. The most internal tendon is inserted into the metacarpal bone of the third finger, external to the attachment of the extensor carpi radialis brevior. The middle tendon is inserted into the base of the second metacarpal bone. The most external divides into two, of which the inner is inserted into the first metacarpal bone, and the outer gives attachment to a second slip of the abductor pollicis. The most internal portion of the muscle can be easily separated from the remainder as high as

the upper third of the forearm, but is distinct from the extensor carpi radialis brevior.

The insertion of an extensor carpi radialis accessorius was described by Mr Wood, and is noted in the list of abnormalities given by Professor Macalister.[1] The muscle described above may be regarded as an extensor carpi radialis longior (having a tendon of insertion into the third metacarpal bone) and an extensor carpi radialis accessorius (Wood) combined.

In a Female Subject, in the left lower extremity.—The *plantaris* is one inch in width at its origin. It arises from the inner part of the posterior ligament and from the inner tendon of origin of the gastrocnemius. The muscular belly terminates in a tendon which passes downwards between the gastrocnemius and soleus, and is attached to the inner part of the tendo achilles.

In a Female Subject, on the right upper extremity.—The *extensor indicis*, which is normal in its origin, terminates in three tendons, of which the inner is inserted into the dorsal expansion of the third finger, and the two outer are inserted into the expansion on the dorsum of the second finger. Cases are recorded where the muscle was inserted into the second and third, and into the second, third, and fourthl (Meckel).[2] The double insertion into the second finger, with an insertion into the third flexor, seems unusual.

In a Male Subject, in the left lower extremity.—The *flexo-brevis digitorum* is normal in position and relation. A muscular slip, continuous behind with the muscular belly of the short flexor, terminates anteriorly in a tendon which is inserted into the internal cuneiform by two slips. One slip at the outer and the other at the inner side of the flexor brevis pollicis. The attachments of this muscle are of interest when viewed in connection with the radio carpus. The latter muscle has been seen in close relation with the flexor sublimis digitorum at its origin, and is inserted sometimes into the trapezium.

In a Male Subject, in the right upper extremity.—The muscles of the forearm are normal. A palmaris longus and a palmaris brevis are present. A *radio carpus* is present, which is attached to the lower part of the oblique bone of the radius contiguous to

[1] "Muscular Anomalies in Human Anatomy," *Proc. Roy. Irish Acad.*, vol. xxv.

[2] Macalister, *op. cit.* p. 106.

the origin of the flexor sublimis digitorum, the muscular fibres which are attached to the posterior surface of the tendon, form a roundish belly three quarters of an inch in diameter, which terminates in a tendon that extends up on the anterior surface of the muscle. The tendon of insertion becomes flat as it descends, and is inserted in the following manner :—internally the fibres are attached to the pisiform and unciform, externally the tendonous fibres are inserted into the trapezium and scaphoid, and the middle fibres into the annular ligament.

A flat muscular band, one inch and a half in width, takes origin from the deep fascia of the forearm three inches above the wrist, and from the tendon of insertion of the previous muscle, descends to the hand and becomes continuous with the fibres of the abductor minimi digiti.

This muscle is a somewhat unusual variety of the radio-carpus. Mr Wood and Dr Macalister found this muscle attached to the annular ligament and co-existing with the ordinary palmaris.[1]

Explanation of Plate XX.

Fig. 1. *ic*, Internal carotid; *ec*, external carotid; *cc*, common carotid; *i*, internal, *e*, external branch of superior thyroid; *s*, subclavian; *ss*, supra-scapular; *sc*, superficial cervical; *v*, vertebral; *it*, inferior thyroid; *ac*, ascending cervical; *a*, internal, *b*, external branch of inferior thyroid.

Fig. 2. *ic*, Internal carotid; *ec*, external carotid; *cc*, common carotid; *f*, facial; *l*, lingual; *o*, occipital; *st*, sterno-mastoid; *sup. t* 2, upper superior thyroid; *hy*, hyoid branch; *sup. t* 1, lower superior thyroid; *l*, laryngeal artery; *sc*, superficial cervical artery; *ss*, supra-scapular; *s*, subclavian; *a*, internal; *b*, external branch of the inferior thyroid artery; *it*, inferior thyroid artery.

[1] Macalister, *op. cit.* p. 91.

THE PATHOLOGY OF A CASE OF FATAL EAR DISEASE. By P. M'Bride, M.B., and Alexander Bruce, M.B. (Plate XXI.)

The specimens which are about to be described were taken from a patient who died in the Royal Infirmary of Edinburgh under the care of Professor Grainger Stewart, to whose kindness we are indebted for permission to describe the *post-mortem* appearances. As clinical facts would be out of place here, we shall only touch upon them where the allusion is absolutely necessary.

EXAMINATION OF THE EAR. By P. M'Bride.

I only saw the patient once during life. At that time (three days before death), she was able to give intelligent answers to questions. The case was evidently one of long standing suppuration of the right middle ear, perforation of the tympanic membrane, and retention of masses of thickened pus, with considerable deafness on the same side. On the other side the hearing was normal. The tuning fork, when placed on the forehead, was heard best in the deaf (diseased) ear, thus showing that three days before death the right auditory nerve and labyrinth were healthy.

The right temporal bone was removed and carefully examined, but not a trace of caries or necrosis could be found. The only abnormality (if, indeed, it may be so called), was that the hiatus Fallopii was somewhat larger than usual, and the large petrosal nerve, which passes through it, gave way on very slight traction.

The next step in the dissection was to chisel away the roof of the tympanum. When the tegmen tympani was removed the tympanum seemed to be filled with a yellowish-white cheesy material, having the consistence of clotted cream. The chisel was then carried through the roof of the mastoid antrum,[1] which

[1] The mastoid antrum, or horizontal portion of the mastoid process, is the large cavity which lies above and behind the tympanum, with which it communicates by what is commonly called the opening of the mastoid cells. Very generally this cavity extends further outwards than the attachment of the membrana tympani, and could be reached by perforating the roof of the bony meatus. —(Von Troeltsch, *Ohrenheilkunde*, p. 176.)

was also seen to be packed with the same caseous material. Microscopic examination showed the latter to consist of pus corpuscles in all stages of degeneration, oil globules, a considerable number of cholestearin crystals, rod-shaped bacteria, and some large epidermoid-looking cells. According to Von Troeltsch,[1] these large flat squamous cells occasionally occur in the mucous membrane of a normal mastoid antrum. More frequently, however, they occur where the cavity is filled by retained pus, and are probably in part due to the pressure exerted on its walls. It seems probable, if this state of things continues long, the pus gradually loses its watery constituents, the large cells increase in number, cholestearin crystals are produced, and ultimately we have the liquid product changed into a solid mass of flat epithelium and cholestearin,—the molluscous tumour of Toynbee.

Having studied the nature of their cheesy contents, the tympanum and mastoid antrum were washed out to see the condition of the mucous membrane lining them. That of the tympanum was found to be enormously thickened, so as to fill up a great part of the cavity. Microscopically, the thickening was found to be due to increase of the connective-tissue elements. The lining of the mastoid antrum was also thickened, but still smooth and glistening. Of the membrana tympani, only a small portion at the edges was left. All the ossicles were absent, with the exception of the foot-plate of the stapes, which was afterwards dissected out from the fenestra ovalis. Neither tensor tympani nor stapedius was visible. The external auditory meatus was somewhat narrowed, as is frequently the case in long-standing suppuration of the middle ear.

It was next desired to find out the condition of the mastoid cells proper. For this purpose the mastoid process was sawn through in various directions. Instead of the ordinary cellular structure, the whole was found to consist of dense ivory-like bone. Portions of this were prepared and cut into sections. Under the microscope these revealed the ordinary structure of compact bone. The Haversian canals were not very numerous, but at parts there were spaces of various size filled with reticular tissue. It differed from that usually found in diploetic spaces, in that it was much denser and altogether had a more

[1] *Lehrbuch der Ohrenheilkunde*, p. 463.

organised appearance. Its meshes contained no fat. This tissue was carefully examined at its margins to see if there was any tendency to a development of new bone, but such was not found to be the case. That in the normal mastoid process many of the bony cells contain diploe, and not air, was pointed out by Zuckerkandel lately in the *Monatsschrift für Ohrenheilkunde* (1879, No. IV.). The external part of the tympanum, &c., was then removed so as to leave that portion of the petrous bone, which contains the cochlea, vestibule, and semicircular canals. This was then divided into two parts in the direction of the axis of the external auditory meatus. By this means the vestibule was opened into. In it was seen a whitish material, which, on being examined under the microscope, revealed pus cells and oil globules. The two portions of bone, containing respectively the semicircular canals and the cochlea, were then prepared and cut into sections.

Those of the cochlea seemed to show a complete disorganization of that delicate organ, and the presence of a small quantity of granular debris with one or two leucocytes. I say, seemed to show, because the cochlea is difficult to prepare, and in the study of its morbid anatomy one can afford to place more reliance on positive than on negative results.

In the sections of that portion of bone containing the semicircular canals no good section of a membranous canal was obtained, except at the ampullæ. I may, however, mention that the membranous canals are exceedingly difficult to demonstrate even in the healthy ear. The sections, however, revealed a most interesting state of things. The whole portion of bone was infiltrated with bacteria. The preparations which showed this best were those which had been stained first with osmic acid and afterwards slightly with picro-carmine. On examining the surface of the bone generally it was seen to be crowded with rod-shaped bacteria. These were abundant both on and between the lamellæ. The perivascular spaces (the probable lymphatics) of bone were uniformly full of them. In the coats of the larger arteries they were seen, and also around the margins of their lumen. In some of the preparations longitudinal sections of the Haversian canals were obtained with a contained vessel. On and around the vessel rods were seen in great abundance

(see fig. 1). The veins, which were distinguished by their thin walls and irregular lumen, for the most part contained plugs, which on close inspection were distinctly seen to be made up of enormous masses of rod-like bodies (bacteria) (see fig. 2). In sections of that part of the temporal bone containing the semicircular canals we meet with numerous spaces, empty for the most part, but some of which contain a reticulum with vessels, fat, and leucocytes. In those spaces which contained diploe the bacteria were present in great abundance; but in the empty spaces a few only were present round the edges. The same applied to the bony canals. In many of these specimens a transverse section of the facial nerve was obtained. Some of the organisms evidently had passed through the sheath, and could be seen lying between the nerve fibrils. In some of the preparations some glistening masses of micrococcus were seen, but they were few in number.

The pathological appearances which have just been described are of considerable interest. Most of them require no further remark, as the facts speak for themselves, but two points must, I think, be noticed more in detail.

1. How are we to account for the presence of pus in the vestibule and cochlea? It will be remembered that, three days before death, the patient heard the tuning fork best in the affected ear, when its stem was placed on the forehead, and from this we were entitled to say that at that time the organs for the perception of sound (labyrinth and cochlea) were intact. The explanation must probably be sought in the hypothesis, that between the day on which the ear was examined and the patient's death, the pus forced its way into the vestibule. I regret extremely that I did not carefully investigate the condition of the membranes of the fenestræ, and therefore cannot speak positively about this. It is, however, quite conceivable that the subjective symptoms which one would expect from such an occurrence might in a case of brain disease be masked by those of the cerebral malady.

2. We must consider the channel by which the bacteria entered first the temporal bone in the neighbourhood of the semicircular canals, and then, as we shall see from Dr Bruce's report, the cerebellum.

Politzer has demonstrated an anastomosis between the vessels of the middle ear and those of the labyrinth.[1] Now, of course, the bacteria were generated by putrefactive changes in the cheesy pus which filled the tympanum and mastoid antrum. The ulcerated condition of the mucous membrane lining the tympanum would readily admit of the parasites getting into the circulation, both sanguineous and lymphatic, and so produce the pathological condition we have been considering.

The fact demonstrated by our case that bacteria may make their way through bone, which, but for their presence, is to all appearance healthy, gives us a possible explanation of cases of cerebral abscess, which, though originating in suppuration of the middle ear, are still separated from the temporal bone by a portion of healthy brain substance. Von Troeltsch (*Ohrenheilkunde*, p. 455) seems to think that many of the evil results of long-continued chronic middle ear suppuration are attributable to pathological conditions such as we have described. According to him, also, general pyæmia may be brought about in the same way from ear disease, but he does not state that he has actually seen the organisms on their way through the bone. Dr Binswanger has, in the *Breslauer Arzt. Zeitschrift*, alluded to the same subject. Unfortunately I have not been able to obtain his paper, but only a *resumé* of it as given in the *Zeitschrift für Ohrenheilkunde* (Band viii. Heft iv.) which runs as follows:—"The author then treats of (erörterd) the manner in which the inflammatory process spreads, and arrives at the conclusion that the parasitic organisms present in otorrhœa make their way along the spaces in the connective tissue surrounding the blood-vessels; that they then get into the circulation, and may cause metastatic abscesses in a remote part of the brain."

Of course bacteria from the tympanum might reach the cerebral circulation by any of the vascular channels which communicate between the middle ear and intra-cranial space, but in the case before us it seemed probable that they entered through

[1] *Lehrbuch der Ohrenheilkunde*, by Politzer. "In neurer Zeit unternahm ich eine Reihe anatomischer untersuchungen, welche zu dem Resultate führten dass Gefässverbindungen zwischen dem Mittelohre und dem Labyrinthe durch die, die beiden Abschnitte trennende Knochenwand, stattfinden" (page 52).

the inner labyrinthine wall of the tympanum, because they were only found in that part of the temporal bone around the semicircular canals. Unfortunately permission was only obtained for examination of the head, so it is impossible to say whether there were any indications of pyæmic processes in other organs.

With regard to the drawings illustrating this case, it will be observed that the bacteria appear to be scattered over the whole surface of the bone alike. Now, it seems difficult to explain why this should be so. We must, however, remember that the sections we have described were cut from decalcified bone, and that such sections do not show the canaliculi well, so that many of the organisms which appear to lie in the matrix of the bone may be contained in canaliculi. Others may owe their position in the matrix to accidental displacement.

My best thanks are due to Dr Hamilton for his kind assistance in preparing and examining the sections, and also to Mr J. Thomson for so ably representing the microscopic appearances on paper.

THE CEREBELLUM. By ALEX. BRUCE.

An abscess the size of a large walnut was found in the right lobe of the cerebellum towards the outer half. It was filled with green, viscid pus; large numbers of punctiform hæmorrhages were found round it. The wall was ragged and the pus particularly fœtid. The cerebellum at this part was adherent to the posterior aspect of the petrous portion of the temporal bone, one-half inch outside of, and one-quarter inch below, the internal auditory meatus, and the nerve entering the latter seemed to be uninvolved. At the point of contact of abscess and bone the dura mater had sloughed. The other parts of the brain were normal.

The fœtid odour of the pus was explained on microscopic examination, scrapings of the pus being found to contain great numbers of rod-like bacteria similar to those found in the petrous temporal bone, and glistening granular bodies which resisted the action of glacial acetic acid, and which were probably micrococci. The hæmorrhages described varied in size up to

the head of a small pin: most were circular in form, and nearly all of them had a light centre surrounded by a rust-coloured ring. In the light centre, in some instances, the walls of a vessel could be seen. The rust-coloured ring was composed for the most part of closely aggregated red corpuscles, which were also infiltrated for some distance into the surrounding tissue of the cerebellum. In several instances, where a longitudinal section of a vessel was obtained, the lumen of the vessel was seen to be completely occluded by blood corpuscles, while the perivascular lymphatic space was distended by white corpuscles, either leucocytes or pus cells, and intermixed with a few red corpuscles. Search was made by clearing up some of the sections with glacial acetic acid for the presence of bacteria or micrococci, but though there were found numerous glistening granular bodies resembling those in the pus, and described as micrococci, they were too sparsely distributed to enable us to pronounce with any certainty as to their exact nature. In one instance only a distinct cluster of rods was seen in the perivascular space, and a considerable number of isolated granules, apparently micrococci. In the neighbourhood of the occluded perivascular spaces the tissue of the cerebellum was infiltrated with leucocytes. The mode of production of these appearances would seem to be somewhat as follows:—The bacteria, on reaching the dura mater, probably set up a localised meningitis, and shortly after, or co-incidentally with that, infected the cerebellum itself, setting up a septic inflammation, which ended in the formation of the fœtid abscess above described, and in the sloughing of the dura mater. The channel of infection of the substance of the cerebellum is probably the perivascular lymph space and not the blood-vessels. Although in one instance only bacteria could be detected in these spaces, yet the occlusion by leucocytes of the lymph spaces seen on longitudinal section of the vessels can only satisfactorily be accounted for on the hypothesis that the irritation travelled along them. This occlusion would probably have resulted in the formation of a thrombus in the vessel, and, from the increased pressure thrown upon the collateral vessels, in the punctiform hæmorrhages already described. These together would lead to the malnutrition and abscess formation in the brain substance, and had the patient

lived longer, we might expect the changes at the seat of hæmorrhage to have gone on to the formation of a second septic abcess similar to the first.

Explanation of Plate XXI.

Fig. 1. *a*, Bone infiltrated with bacteria; *b*, artery with some bacteria lying on it; *c*, perivascular space containing numbers of bacteria.

Fig. 2. *a*, Bone infiltrated with rod-shaped bacteria; *b*, vein filled with bacteria and a few corpuscles and leucocytes; *c*, small artery; *d*, perivascular space containing numerous bacteria.

NOTES ON THE DISSECTION OF A CASE OF CONGENITAL DISLOCATION OF THE HEAD OF THE FEMUR.

By Francis J. Shepherd, M.D., C.M., M.R.C.S., Eng., *Demonstrator of Anatomy, M'Gill University, Montreal.*

A female subject about 50 years of age was brought to the dissecting-room of M'Gill University in the autumn of 1879 in whom it was noticed that the right leg was smaller and shorter than the left, and everted. The woman was very stout, and the head of the femur could not be distinctly made out, but it was noticed that the trochanter was higher than usual; abduction was limited, but otherwise the joint was freely movable. The tuberosity of right ischium was quite subcutaneous, the muscles appearing as if carried up with the trochanter-major. Amount of shortening, 2 inches. The exact nature of the lesion was not made out from an external examination, and it was only on dissection of the part that it was discovered to be a congenital dislocation.

Dissection.—There are no scars to be seen on the skin of gluteal or femoral region, indicating that old sinuses had existed, the skin is perfectly smooth. On removing the skin and fascia of the gluteal region, the fibres of the gluteus maximus, and gluteus medius muscles are found to be shorter than normal, their points of origin and insertion being approximated; the muscular tissue is much altered, in some places being completely changed into fatty tissue. I may here remark that all the muscles of the body have become fatty degenerated to a greater or less extent, but this condition is much more marked in some of the muscles about the affected hip. On removing the two superficial gluteal muscles (between which a lot of fat is seen), the quadratus femoris, obturator externus, gemelli, and obturator internus are brought into view. These muscles, instead of passing transversely outwards to get to their insertion, pass upwards; the pyriformis is found to pass outwards and slightly upwards, instead of downwards. The gluteus medius, obturator internus, gemelli, and pyriformis in passing to their insertions go over the head of the femur. More of the obturator externus is

exposed to view than usual; this muscle passes upwards to the great trochanter close to the old capsule, which is seen lying between it and the gluteus minimus; the obturator externus is much longer than normal, and is quite a strong muscle, the tissue of which is healthy and without any trace of fatty degeneration. The gluteus minimus is shortened, and nearly all composed of fibrous tissue, it is pushed upwards by the ascent of the great trochanter, and has a smaller origin than usual, owing to the space on the dorsum of the ilium between the middle and inferior curved lines being partly occupied by the new socket for the head of the femur. This muscle covers the head of the femur, and is so closely united to the new capsule that it can only in places be separated from it.

The adductors and gracilis muscles are shortened and tense, and have participated but slightly in the general degeneration; the pectineus is smaller than usual, its outer portion being fibrous; it is attached as usual to the shaft of the femur. The iliacus internus muscle has nearly all atrophied away, and now consists of a very thin flat layer of muscular fibres, streaked with fat, which become united to the tendon of the psoas magnus, an inch above Poupart's ligament, so that none of its muscular fibres are seen below this ligament; above and below this muscle in the iliac fossa is a large deposit of fat. The psoas magnus has the usual origin, but consists almost entirely of fatty tissue, streaked here and there with muscular fibres, it ends in a flat tendon a little higher up than usual, and after being joined by the wasted iliacus muscle passes as a narrow, thin, ribbon-like tendon in the groove below the anterior inferior spine of the ilium under Poupart's ligament, in a direction outwards and upwards, and becomes blended with the anterior part of the old capsule.

Ligamentous Structures.—Two capsular ligaments are seen, the old and the new. The *old capsule* is still attached to the margin of the acetabulum, and is much thickened; the ilio-femoral ligament is well marked, being strengthened by the blending with it of the tendon of the psoas and iliacus muscles. The capsule is stretched upwards and outwards, following, of course, the ascent of the head of the femur; in its upper and posterior part is seen the head of the femur protruding through

a slit; this slit embraces the neck of the femur, and it appears as if the head of the femur has worn away the capsule at this point by pressing it against the dorsum ilii. The *new capsule* is attached at its pelvic extremity around the socket which has been formed on the dorsum ilii by the wearing away of the bone, —at its femoral end it is attached internally to the slit in the old capsule through which the head of the femur protrudes, and externally is continuous with the inner surface of the gluteus minimus. It is ligamentous in structure, its inner surface is smooth, and a number of small villous processes are seen hanging from it. No synovial fluid can be seen. The *ligamentum teres* is entirely absent, no trace of it being seen either in the old acetabulum or in the head of the femur; it has probably been worn through and the two ends absorbed.

Osseous Structures.—Femur. The whole bone is perceptibly smaller than that of the opposite side. The head is remarkably altered in appearance, it is of less size than normal, and where the ligamentum teres should be attached it is flat and devoid of cartilage, as if it had been worn away or had lost its epiphysis; on the upper part of this flattened surface a shallow groove is seen, crescentic in form. The remaining part of the head is covered with cartilage. The compact bony tissue covering the head is remarkably thin, and on breaking it through the cancellated structure is found to be very soft. The neck of the bone is much shortened, and forms a right angle with the shaft; the upper part of the shaft is arched outwards; where the gluteus maximus was attached a rather prominent crest is seen. The *lesser trochanter* is absent, its place being occupied by a shallow groove.

Pelvis.—The whole right half is smaller than the left. The wing of the right ilium is much thinner, more upright, more curled inwards, and altogether smaller than the left; the anterior inferior spine is prominent, and in consequence the groove below it in which lay the tendon of the psoas and iliacus is deeper. The rami of the pubis and ischium on the right side are flatter, thinner, and seem to spread out more than those of the opposite side, that is if a perpendicular be dropped from the symphysis pubis, the angle formed by it with the rami of the right side is much more obtuse than that formed by it with the

rami of the left. The right obturator foramen has lost its triangular shape, and is now broadest in its transverse diameter. The *acetabulum* is much altered in appearance, being a mere triangular depression in the bone; the apex of the triangle is upwards and to the right, and the base corresponds to the cotyloid notch. The edges of this triangular depression are smooth and curled inwards, and but slightly covered with fibro-cartilage; the transverse ligament has almost disappeared. Around the edges of the depression is attached the old capsular ligament. The bottom of the cavity is completely ossified, and shows no trace of any disease having existed, the depression for the Haversian gland is well seen, it is small, being about the size of a sixpence. The acetabulum measures two inches in length, three-quarters of an inch in breadth, and half an inch in depth, it was filled with fatty tissue. The *new socket* for the head of the femur is an oval depression on the dorsum ilii between the middle and inferior curved lines, and on a level with the great sciatic notch, the inner edge of this new socket corresponding to the bony edge of the notch. It has not been deepened by ossific deposit, but appears to have been made by the wearing action of the head of the femur. It is two inches in diameter and a quarter of an inch in depth. Around its edge the new capsule is attached, and its floor is covered by a sort of periosteum, which receives fibres from the capsule. The ilium is not very thin at this point.

The measurements of the pelvis are altered, the diameters of the inlet being increased and outlet slightly diminished:—

Diameters.	Inlet.	Outlet.
Conjugate, ...	4¾ inches.	4 inches.
Right oblique, . . .	5½ „	—
Left oblique, . . .	5¼ „	—
Transverse, . . .	6 „	4½ „

The distance between the anterior superior spines of the ilia measured nine inches.

The sacrum is slightly turned to the affected side, but otherwise is not much altered in appearance. There is no great anterior convexity of the lower dorsal and lumbar vertebrae, but the vertebrae incline laterally to the affected side.

Remarks.—(1.) *The absence of anterior convexity* in the lower

dorsal and lumbar regions was probably due to the atrophied condition of the psoas and iliacus muscles and their abnormal attachment to the old capsule. Probably during life, when the woman assumed the erect position, this anterior convexity existed, though not to the great degree that is usual.

(2.) *The absence of the lesser trochanter* was due no doubt to its having been torn away from its attachment to the femur at the time the dislocation occurred, and to its afterwards having been absorbed. This would account for the insertion of the psoas and iliacus tendon into the old capsule, the muscles thus having a very limited action would atrophy. This condition would also favour the opinion held by some that this form of dislocation is due to violence (at birth).

(3.) There was no twisting forwards of the head and neck of the femur, a condition which is described by some, and which, had it existed, would have accounted for the eversion. The eversion of the limb may have been only a *post-mortem* symptom due to the relaxed state of the muscle, the large capsule, and small head of femur.

Note.—The subject in which the above described dislocation occurred, owing to the unfortunate state of affairs in Canada, had been illegally obtained, so that no history could at the time be procured. I have since heard that this woman had suffered from "lameness" all her life, that she walked with a waddling motion, and also that she had borne a large family of children. This information I have fair reasons for supposing is authentic.

ABNORMAL CYSTIC ARTERY. By J. MACDONALD BROWN,

Assistant-Demonstrator of Anatomy, University of Edinburgh.

RECENTLY, in the University Anatomy Rooms, on making a dissection of the superior mesenteric artery in a child, what at first appeared to be two inferior pancreatico-duodenal arteries were observed. Of these the more external had the usual relations of anastomosis, whilst the more internal artery ran obliquely in front of the head of the pancreas, and disappeared behind the first part of the duodenum about its middle.

When the latter artery was traced behind and above the duodenum, it was found after a slightly curved course to reach the gall-bladder, at the neck of which it divided into two branches, to supply the anterior and posterior surfaces. It was a long slender artery, which in its course gave off no branches whatever. A subsequent dissection of the cœliac axis showed, that although the hepatic artery had the usual distribution, its right terminal division gave off no cystic artery. The gastro-duodenal trunk divided in the normal manner, but neither of its two branches in any way communicated with the abnormal artery referred to above.

The gall-bladder was found to receive branches of supply from no other source; so that in this case the cystic artery was derived from the superior mesenteric directly.

Quain states that the hepatic artery occasionally comes off from the superior mesenteric, and the cystic artery has even been found as a branch from the gastro-duodenal trunk, but no similar variety of the arrangement described above seems to have been hitherto noticed, unless the specimen recorded by Wilde (*Comment. Ac. Sc. Petropolit.* 1740, xii. 262) had a similar arrangement.

ON THE PLACENTA OF THE GENUS *TRAGULUS*. By Professor v. Kölliker. (*Abstracted from Verhandlungen der Würzburger Phys. Med. Gesellschaft*, N. F. Band x.)

The first communication on the fœtal membranes of *Tragulus* was by v. Babo in 1847, who stated that the chorion of this animal showed no trace of cotyledons, but was covered with small villi, which were lodged in depressions of the uterine mucous membrane, from which they could be drawn out. A. Milne-Edwards also pointed out that in *Tragulus Stanleyanus*, the chorion was covered with villi, which had only a feeble connection with the uterine mucous membrane. Based on these descriptions it has been customary to separate the genus *Tragulus*, as regards the placenta, from the majority of Ruminantia and to place it along with the camels, amongst the mammals possessing a diffused placenta.

Kölliker has examined a specimen of the gravid uterus of a *Tragulus*, which was perhaps *Tragulus Kanchil*, that has been preserved for at least thirty years in the Würzburg Museum. The surface of the chorion opposite the os uteri was apparently free from villi. Cotyledons of the ordinary kind were certainly absent, but the uterine mucosa was in places raised into little wart-like elevations, which presented the appearance of minute cotyledons. The outermost of these cotyledons were completely separated from each other, but by degrees they became blended together so as to form continuous elevations which constituted the chief mass of the placenta. On the surface of these elevations were numerous openings, which received the villi of the chorion. These villi were flattened, and generally simple, although indications of branches were seen at the ends. Where the chorion was in relation to the margin of the miniature cotyledon villi were absent from its surface. All the pits in the cotyledons of the mucosa were lined by an epithelium, which consisted of large, many nucleated cells, which in some respects resembled tessellated epithelium, but were distinguished from it by the number of their nuclei and their more many-sided form. These cells lay close to the epithelial covering of the villi. Opening into some of these pits were utricular glands lying in a deeper plane of the mucosa. In the region of the mucosa, which corresponded to the surface of the chorion free from villi, furrows and depressions on the surface of the mucosa, with true uterine glands also occurred. The villi could be easily drawn out of the pits in the uterine mucosa in which they were lodged.

The amnion had the usual relations. A large umbilical vesicle lay between the amnion and chorion, the vessels in which were distinct and could be followed to the place of insertion of the umbilical cord. It was closely attached to the amnion but easily separated from the chorion. The funis contained two arteries and two veins.

Kölliker considers that whilst the placenta of *Tragulus* differs from

that of the ordinary Ruminants in not having the villi of the chorion so long and so strongly developed, and in not having the corresponding growths of the mucosa so distinct, yet that the connections of these parts with each other differ from and are more intimate than that of the corresponding parts in the pig and mare. Also the placenta uterina of *Tragulus* gives definite indications of separation into distinct cotyledons which are indeed found, though small in size, at the border of the placenta. The uterine glands also do not open as in the pig and mare on the surface of the mucosa, but into the pits in which the villi are lodged. He is of opinion therefore, that, the placenta of this animal is an intermediate form between that of the proper Ruminants and the diffused placenta of the pig and mare.

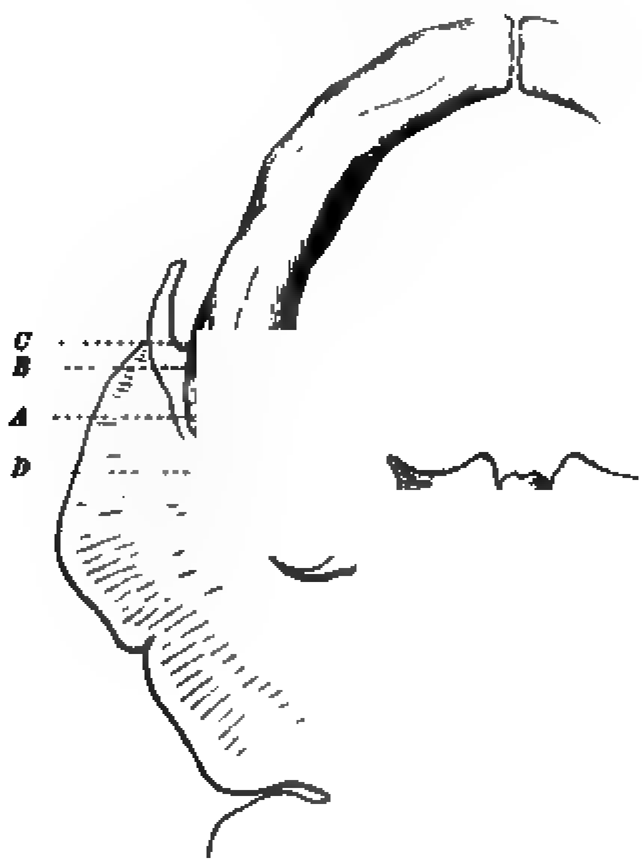
ON THE GRAVID UTERUS AND PLACENTA OF *HYOMOSCHUS AQUATICUS.* By Professors A. H. Garrod and Wm. Turner. (*Abstracted from Proc. Zoological Society, London, June* 18, 1878.)

In contrast with the above description by Prof. v. Kölliker of the placenta of a species of *Tragulus* may be placed that of the placenta of the allied genus *Hyomoschus* also belonging to the family Tragulidæ.

The fœtus was well developed, and measured 7·5 inches from tip of nose to root of tail. It was situated in the left horn of the chorion. The free surface of the uterine mucosa was pitted with multitudes of minute crypt-like depressions just visible to the naked eye. In these crypts the villi of the chorion were lodged. The utricular glands were seen sometimes to open on the slender raised folds of mucosa separating adjacent crypts from each other; at other times they opened into the crypts, or on portions of the mucous membrane where the crypts were very shallow or scarcely perceptible. The mucosa consisted of a gland layer and a crypt layer, the former was next the muscular coat, and consisted of elongated tubular, tortuous glands, occasionally bifurcating and opening on the surface as above stated. The chorion, except opposite the os uteri and the Fallopian tubes, was almost uniformly covered with villi, which were arranged in small tufts separated from each other by very narrow intervals. The villi were short and branched usually in the form of filamentous processes.

The amnion formed a capacious bag in the left horn of the chorion, but did not pass into the right horn. The sac of the allantois occupied the right horn of the chorion and formed a tubular prolongation extending into the left horn to within half an inch of its tip. The funis was 3¼ inches long, and the amniotic investment of the cord was studded with numerous whitish sessile corpuscles. The placenta was a characteristic example of a diffused placenta.

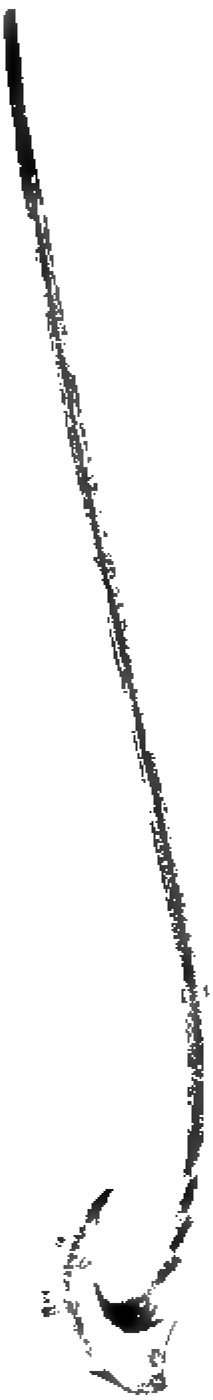
ILLUSTRATION TO MR S. G. SHATTOCK'S ACCOUNT OF A NEW BONE IN HUMAN ANATOMY, P. 201.



The Base of the Skull in the Temporo-Maxillary Region.

A. Processus Gracilis of Malleus.
B. Os Articulare.
C. Spine of the Dental Foramen.
D. Tympanic Bone.

Fig. 1.



n. s

Fig. 2.

Fig. 3

Fig. 4.

Fig. 5.

n. s

Fig. 6.

J H Scott, M D del

F Huth, Lith^r Edin^r

Fig. 1.

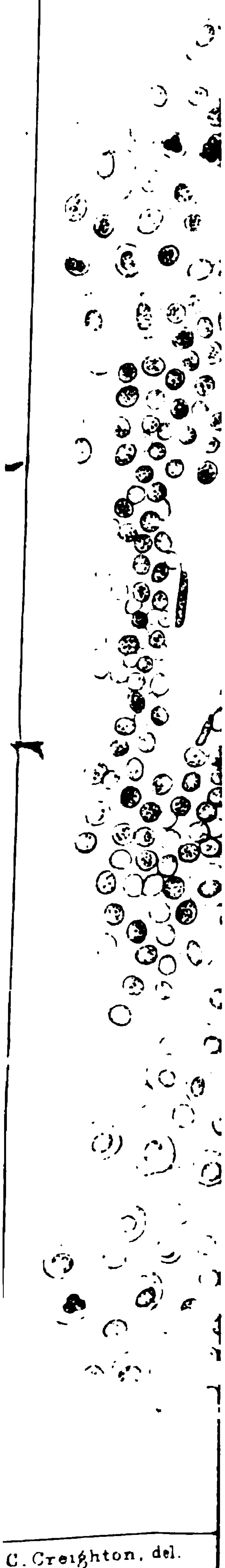
Creighton del

Fig. 2

Fig. 3.

F. Huth, Lith.r Edin.r

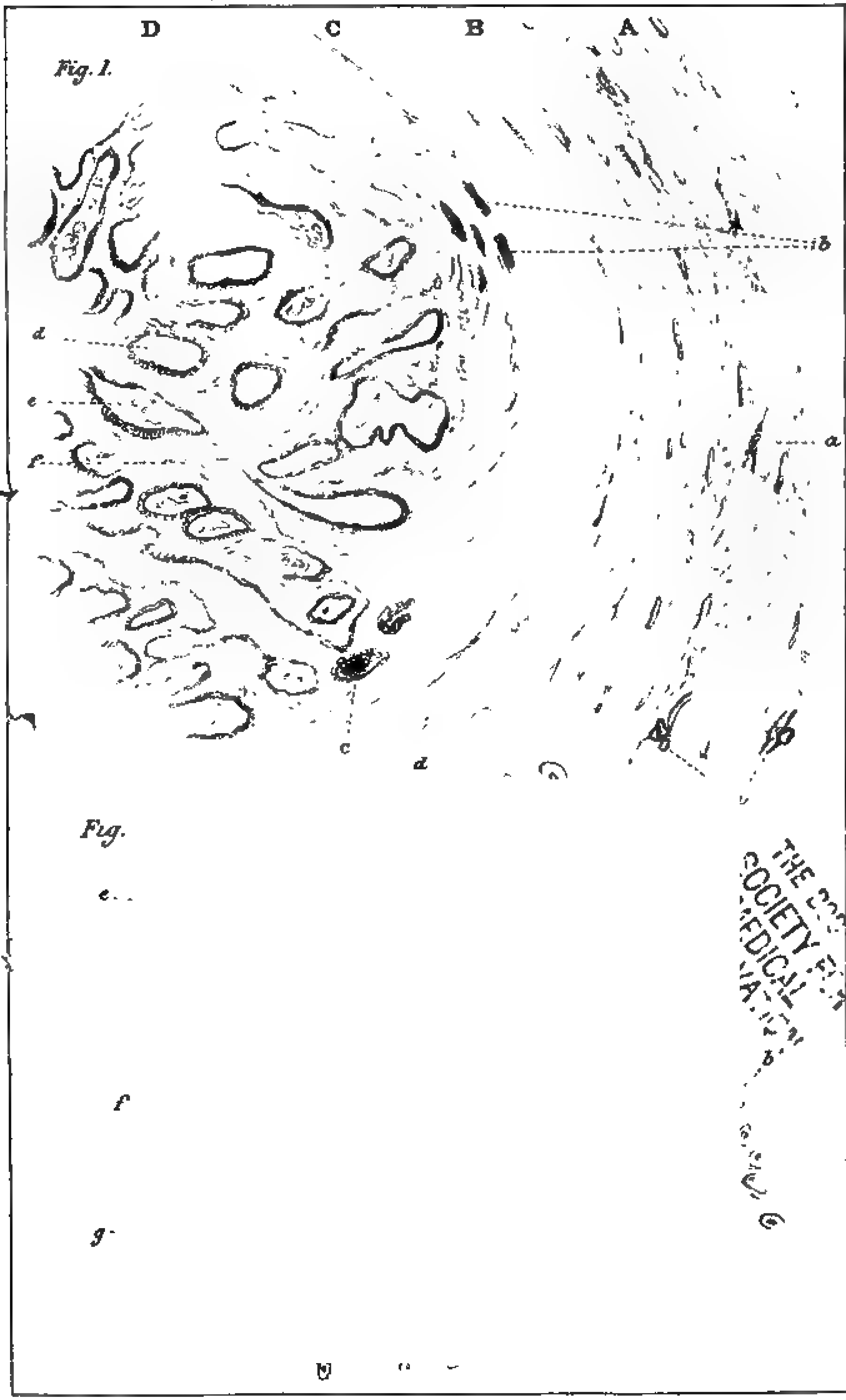
Fig. 9.



C. Creighton, del.

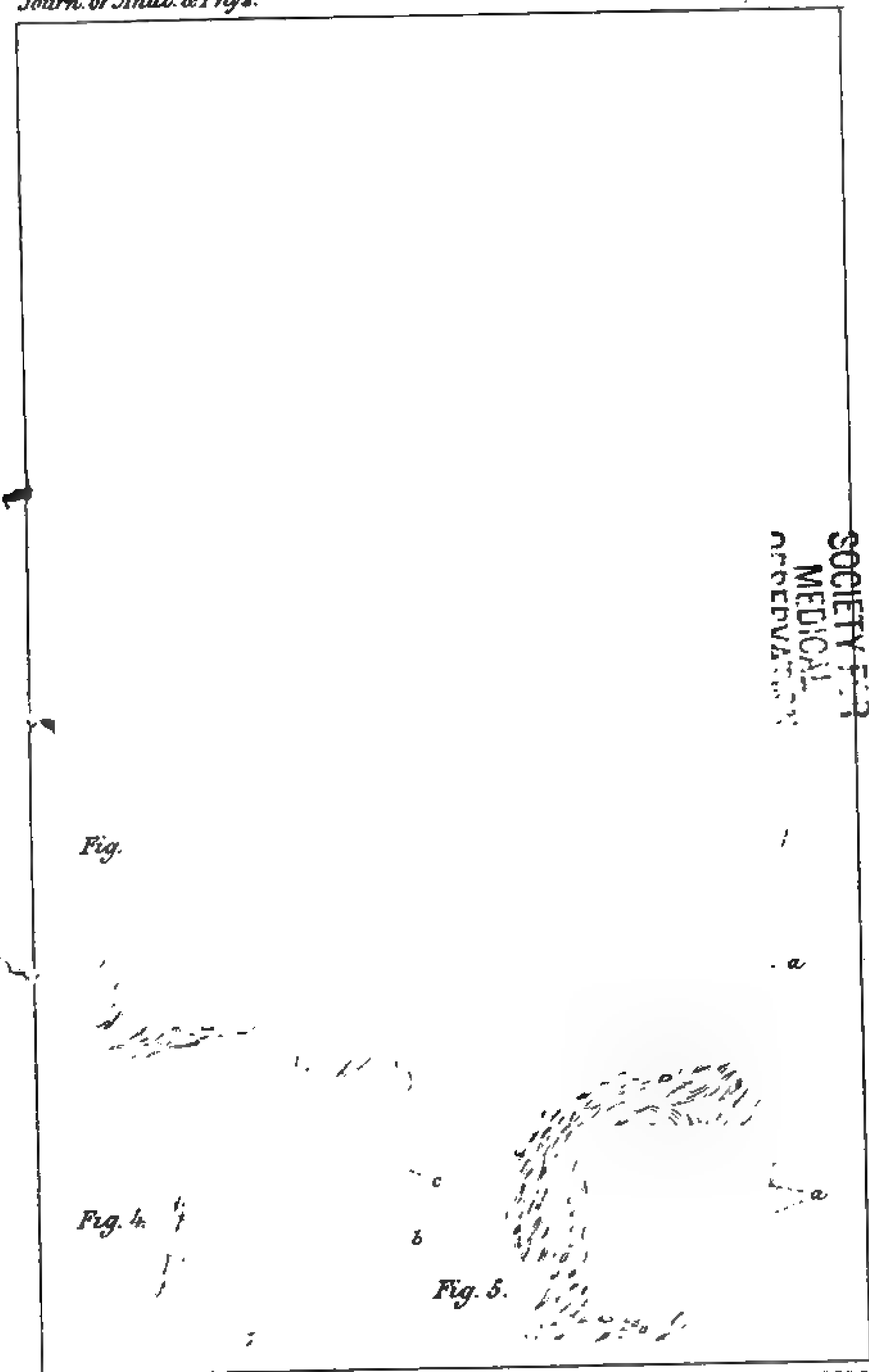
Fig. 9.

C. Creighton, del.



A H Young del

F Huth, Lith.r Edin.r



A H Young, del. F Huth, Lith^r Edin^r

Fig 1

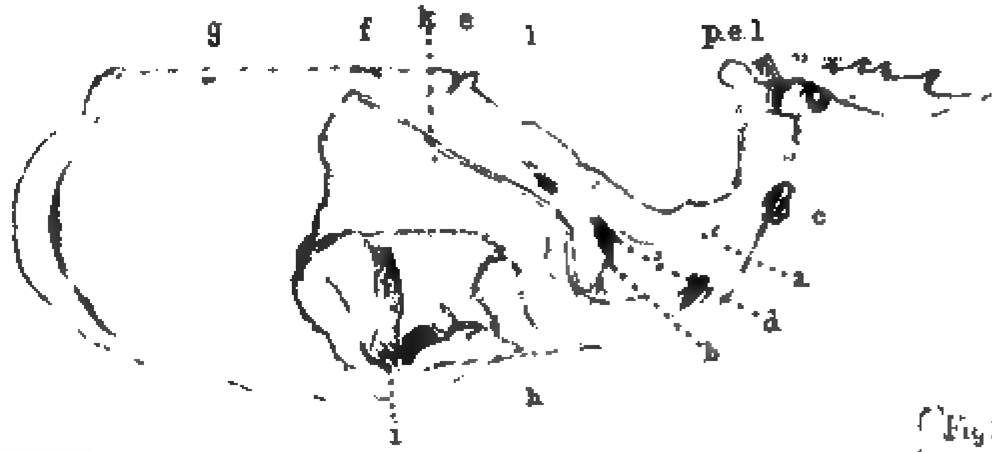


Fig 3

Fig 2

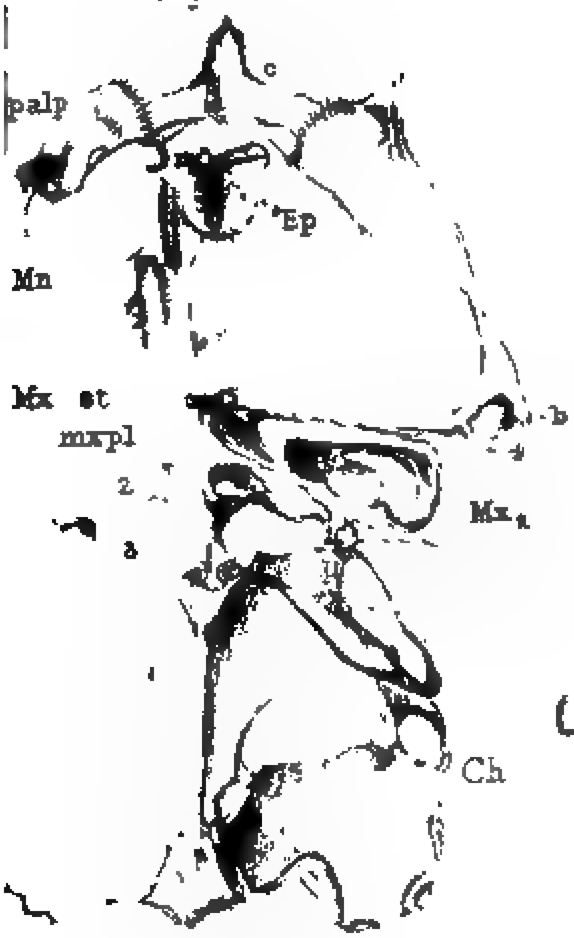
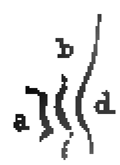
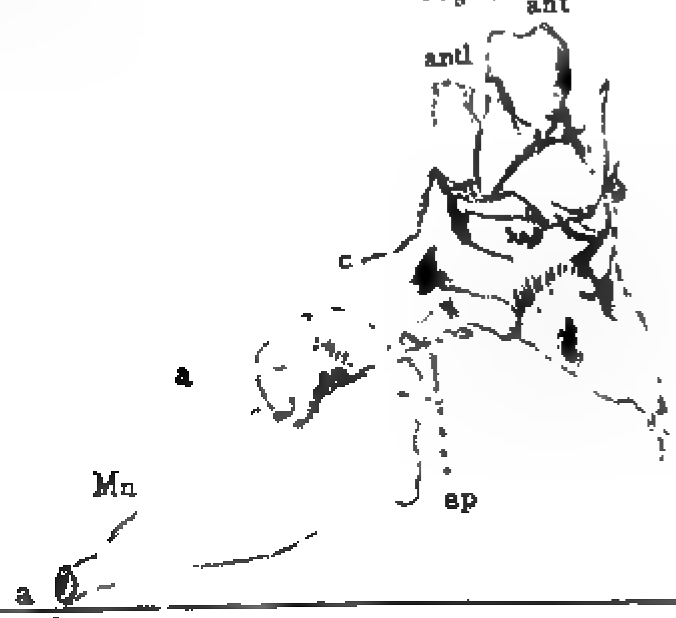


Fig 5



a

Fig 4



Drawn from Nature by W. S. Richmond. On Stone by T. Godart.

West, Newman & Co. imp.

Fig 1

i.c. a.c

s

S.

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Fig 2

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i.c

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b

It

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Fig. 1.

Fig.

F Huth, Lith^r Edin^r

Journal of Anatomy and Physiology.

THE RETE MIRABILE OF THE NARWHAL. BY HENRY SEASON WILSON, M.D., *Superintendent of Practical Anatomy, London Hospital.* (PLATES XXII., XXIII.)

THE specimen on which the following investigations were made was a fœtal Narwhal, 64¼ inches long, and 48½ inches in its greatest circumference. Its mother was captured in 1861 on the north side of Pond's Bay, Davis Strait, by Captain George Deuchars of the screw-steamer "Narwhal" of Dundee. The fœtus was removed at the time of capture by Dr Robert Brown, who kindly permitted me to dissect the soft parts. Owing, however, to the decomposed state of the animal, I could only investigate the vascular system, and even that but imperfectly. My remarks will apply only to the thoracic rete mirabile, and are selected from the notes and drawings taken during my dissections when Demonstrator of Anatomy in the University of Edinburgh in 1862.

It seems unfortunate that the term "rete mirabile" should have been applied so indiscriminately to all vascular plexiform arrangements, for, both anatomically and teleologically, when the various plexuses are compared with each other, a good deal of confusion and a great want of harmony are at once observable. I shall not enter here into that question. It will be best understood and more easily handled when we come to examine into the probable function of retia in general, and especially of the thoracic plexus in Cetacea. Suffice it to say that of all the retia mirabilia throughout the vertebrata, that in the thorax of the Cetacea resembles no other so-named plexus. John Hunter is the only author who has likened it to any other network, and

even that similitude is but trivial, for the spermatic arteries of the Bull resemble it only in the tortuosities of their branches. I will first state the facts evinced by dissection, deferring deductions and other observations for subsequent attention.

As the thoracic rete mirabile in the Narwhal is arterial, and its position is by the side of the thoracic aorta, in order to understand the sources whence the vascular supply is derived, a brief enumeration of the modifications exhibited by the primary branches of the aortic arch and the thoracic aorta are necessary.

Aortic arch.—The arch lay at first entirely concealed by the pulmonary artery. Beyond this only a narrow portion could be seen, owing to the close manner in which it was embraced by the lobes of the thymus (Plate XXII. *A*). The right lobe separated it from the vena cava anterior, whilst both lobes were interposed between the arch and the pneumo-gastric nerves, more especially on the left. By dissecting away the thymus, the aorta was seen to be continued forwards and to the right for a short distance, and thence to arch obliquely upwards towards the left of the spine. Close to its exit from the left ventricle the aorta supplied its coronary branches, each having its usual origin and distribution. From the convexity of the arch arose the innominate, the left common carotid, and the left posterior thoracic arteries.

The innominate (Plate XXII. *A*, 1) had its origin from the commencement of the transverse portion of the arch, on a level with the head of the first rib, and greatly exceeded the others in size. It extended forwards towards the neck for about half an inch, and then divided into two large branches—the right posterior thoracic, and the right common carotid (Plate XXII. *A*, 3, 2, 11, 8). The right posterior thoracic in its origin and in the relations of its first part resembled the right subclavian, but differed from it in its ultimate distribution. From its origin it arched horizontally forwards and outwards towards the first rib. Reaching the latter at the distance of about three inches from the spine, it suddenly curved backwards, and continued along the inner aspect of the thoracic wall. In this course it crossed the first eight ribs and ended in the eighth intercostal space. It was thus divisible into two portions—the arch, situated in the neck, and the terminal portion related to the ribs, and intrathoracic in

position (Plate XXII. *A*). For the sake of description these portions may be called the arch and the costal portion. The arch was much the shorter, and was cervical in position. It had the usual relation to the innominate vein, the pneumogastric, the branches of the sympathetic, and the phrenic nerves, as well as to the scalenus muscle. At first it was covered by the cervical part of the right thymic lobe. Only one branch, cervical (Plate XXII. *A*, 4) passed from this arch. It arose from the parent trunk, where that was crossed by the right innominate vein. This branch corresponded in its distribution with the "cervicalis ascendens" in man. In addition to its muscular branches it supplied offsets in great numbers to the cervical portion of the rete mirabile, and also formed large anastomoses with the anterior (superior), thyroid, and pharyngeal branches of the external carotid (Plate XXII. *A*). On the left side this branch came from the left internal mammary. The costal portion of the posterior thoracic ended, as above stated, in the eighth intercostal space. In its course it lay, to a certain extent, embedded in the substance of the thoracic portion of the rete, running along the external margin of the rete, and keeping parallel to the spine. Immediately before its termination, however, it diverged from the mesial line. Its branches were very numerous, and were chiefly directed inwards towards the spine, or outwards from it. Towards the vertebral column it gave hundreds of long, delicate offsets, nearly equal in their calibre. These passed entirely to the rete, and a fuller account of their distribution will be more appropriate when considering that network. The branches passing outwards constituted groups which, with the exception of the first, occupied the intercostal spaces from the third to the eighth (Plate XXII. *A*, 16, 7). The first group was given off immediately before the artery entered the thorax, and was much larger than the others. It consisted of numerous branches, directed forwards to the cervical muscles, and backwards to the first and second intercostal spaces. The other groups resembled intercostal vessels, and need not occupy time in minute description. As the right common carotid artery has very little to do with the rete, supplying comparatively very few branches, and those simply to its cervical portion, I shall pass it over.

The left common carotid (Plate XXII. *A*, 2') sprung from the

aortic arch, at a distance of about three quarters of an inch from the innominate trunk. In size it was somewhat more than half the calibre of the latter. Its course was forwards, and slightly outwards. Within the thorax it was related externally to the narrow anterior prolongation of the left thymic lobe, by which it was separated from the left pneumogastric, and internally it was in contact with the thyroid body. Its cervical portion need not be described.

The left posterior thoracic (Plate XXII. *A*, 3′), in its place of origin, resembled the left subclavian in man; that is, it arose from the left aspect of the last portion of the aortic arch, directly opposite, but immediately preceding the ductus arteriosus. It was an inch and a half beyond the left common carotid, and about half its size. Its course was forwards to a level with the first rib and then backwards to end in the ninth intercostal space. The arch was intrathoracic and very short. It had the same relations to the sympathetic and pneumogastric as the corresponding subclavian in man. Its only branch was given off as it neared the first rib. This branch soon broke up into a number of offsets, and represented the first group of the costal portion of the right posterior thoracic (Plate XXII. *A*, 6′). The costal part of the left posterior thoracic extended one intercostal space beyond that of the same branch on the left side. It supplied the same innumerable branches inwards to the rete, and similar intercostal groups outwards. The first group, already mentioned, resembled that on the right side in supplying the first and second intercostal spaces. It may here be added that these intercostal groups anastomosed freely with corresponding intercostal branches of the internal mammary arteries, and the last or terminal group also inosculated with those aortic intercostals supplying the neighbouring intercostal spaces.

Between the origins of the left common carotid and the left posterior thoracic, but closer to the latter, a very small fourth branch arose from the aortic arch. It was directed forwards to supply the apex of the left thymic lobe, and then ended in the left mass of the rete mirabile (Plate XXII. *A*).

Thoracic aorta.—The thoracic aorta occupied the usual position along the spine as far as the diaphragm. Its relations were similar to those in man, with this exception, that the rete

separated it from the spinal column. Its branches, seven in number, corresponded with the intercostal arteries, and arose from the vertebral aspect of the trunk, not in pairs, but as single offsets. These branches varied considerably in size. From the first to the fourth there was a gradual decrease, whilst the last three became greatly enlarged. The direction of the individual branches also differed. The first three passed slightly forwards to reach their destination, but the last two inclined backwards. Each terminated in two lateral branches at variable distances from its origin. These lateral divisions coursed along the transverse vertebral grooves and ended in branches which were destined to supply, some the rete mirabile alone, others partly the latter and partly the intercostal muscles. Their ramifications in the intercostal spaces were peculiar in that the branches of distribution passed off at acute angles from the trunks. As the same description does not answer for all, each must be examined separately. The first intercostal artery came off from the aorta at a level somewhat posterior to the fifth intercostal space, and, turning forwards, soon broke up into two divisions. One of these divisions continued onwards and subdivided into lateral branches to supply that portion of the rete corresponding with the two fourth intercostal spaces. The other division also became bifid, the resulting branches being spent in the meshwork of the rete occupying the fifth interspaces. The second, third, and fourth intercostals branched almost directly into lateral divisions, and were lost in the rete under the sixth, seventh, and eighth interspaces respectively of the right and left sides. The fifth intercostal artery was a very large branch comparatively. Its lateral divisions were very unequal in size. That to the left far exceeded the other, and was in calibre the continuation of the parent trunk. It coursed along the transverse vertebral groove into the ninth intercostal space, lying above the constituent vessels of the rete. Having reached the space it subdivided into two unequal offsets. The smaller of these ran along the middle of the interspace and anastomosed with the ultimate twigs of the posterior thoracic and musculophrenic arteries, whilst the larger offset turned obliquely backwards and followed the last rib. In its course along the rib it first supplied a considerable branch to the tenth interspace, and

then terminated in offsets to the abdominal muscles on the one side, and the intercostals on the other. These terminal offsets of the left lateral division, as each passed along its intercostal space, supplied dorsal vessels which pierced the intercostal muscles and ended in the dorsal vertebral muscles, and while beneath the rete each, as well as the parent trunk, distributed numerous delicate twigs to that network. The right lateral division of the fifth intercostal was similar in size and distribution to those of the preceding. It was lost in that part of the rete opposite the ninth interspace. The sixth intercostal branch was the largest of the last three. Its lateral divisions were proportionately as unequal in size. That to the left, the smaller, continued entirely imbedded in the rete, as far as the intertransversales, through which it passed to end in the dorsal muscles of the spine. Whilst surrounded by the rete it gave to the latter a large supply of delicate, slender branches. The right lateral division subdivided into two branches opposite the head of the tenth rib. The smaller of these, after sending a dorsal muscular offset, coursed along the ninth rib and was lost, partly in distribution to the ninth and eighth interspaces, and partly in anastomoses with the last ramifications of the posterior thoracic and musculo-phrenic arteries. The larger branch gave origin also to a dorsal muscular offset, and, continuing outwards for a short distance, bifurcated for the supply of the last two intercostal spaces. The whole of the right lateral division as well as part of its subdivision were covered by the rete to which they distributed innumerable vessels. The seventh of the intercostal series of branches corresponded to a "last dorsal." Its course, being close to the posterior margin of the last rib, was in the abdominal wall. It was the smallest of the last three, and its lateral divisions were, like those of the others, unequal in size. That to the left, the larger, was directed above the rete mirabile as far as the posterior border of the head of the eleventh rib, along which it ramified, supplying the muscles in that region, and communicating with offsets from the fifth intercostal artery. When lying above the rete the latter received a rich supply of vessels, and when lying on the intertransversales it gave a dorsal muscular branch. The right lateral division was exceedingly small, and soon broke up into numerous twigs for

that portion of the rete corresponding with the tenth intercostal space.

Now that the main branches, whence the rete mirabile derives its vascular supply, have been described, the position of the principal part of the rete, that is, its thoracic portion, as well as the relations it bears to the thoracic vessels, will be easily understood.

By the thoracic rete mirabile is understood that large mass of anastomosing vessels situated along the centre of the dorsal wall of the thorax. For convenience of description it may be said to consist of two elongated lateral masses, each lying athwart the ribs, and close to the side of the spine, the lateral masses being connected to each other by an intermediate central band, similarly constituted, and arching over the vertebral bodies. Each lateral mass measured 3 inches in breadth. They both preserved their characteristic arrangement and structure from the base to the apex of the thorax, but beyond these limits they became altered and comparatively insignificant. Their extension into the abdomen was scarcely perceptible, though their prolongation into the neck was more distinct and more readily traced. The intermediate band had the same extent in an antero-posterior direction, but was only 1½ inch in breadth. The whole mass had thus a transverse measurement of about 7½ inches. As the rete closely invested the structures over which it lay, it necessarily varied considerably in thickness. This was greatest nearest to the vertebral bodies where the anastomosing mass sunk deeply between the transverse processes and the heads of the ribs, and into the hollows of the vertebral grooves. It was least in the intermediate central band, which but thinly covered the bodies of the vertebræ. The parts of the thoracic wall concealed by the entire rete mirabile were the bodies of the dorsal vertebræ, the intervertebral foramina, and part of the ribs with the corresponding portion of their intercostal muscles. Though the meshwork closely invested these structures, fitting accurately into all the inequalities of their surfaces, yet the connective tissue between them and the rete was of such a loose nature as to permit the entire mass to be reflected from them without much dissection. It was most firmly adherent over the transverse processes and heads of the

ribs. The opposite aspect of the rete was almost entirely in contact with the pleura. The thoracic aorta, however, crossed lengthwise along the left of the central band, but the lateral masses were covered only by the pleuræ. The free margins of the rete, well defined on each side, kept parallel to the spinal column, and were bounded along nearly the whole of their extent by the two posterior thoracic arteries.

The three principal sources whence the rete mirabile derived the vessels entering into its composition were the posterior thoracic arteries on each side, and the thoracic aorta in the middle. The anastomotic vessels of the posterior thoracics branched in vast numbers from those portions of their trunks and of their intercostal offsets which were above the rete. As they emerged from these sources these branches presented one of the most beautiful of anatomical objects. The delicacy of their coats, the vast immensity of their numbers, their gently sinuous courses, their almost equal calibres, and their almost equally distanced origins at once marked them as peculiarly characteristic and uncommon. They soon became lost in intricate meanderings which, with care and patience, were gradually unravelled and their ramifications traced into the substance of the labyrinthine maze. These ramifications will be best understood by following as far as practicable any given branch. Quitting its parent trunk as a minute vessel it entered the rete with a sinuous course, retaining the same calibre throughout this extent. Once within the mass it lost its wavy undulations and wandered very tortuously. At the same time it became sometimes rapidly, sometimes gradually, widened into twice, thrice, and even four times its former size, and distributed here and there, at irregular intervals, secondary branches, having its own calibre, or occasionally rather smaller. Passing onwards in its intricate course, it branched on all sides until at last its individuality was lost in the complex network of the anastomotic maze. Its secondary branches each presented a like distribution, and supplied tertiary offsets, which in their turn but repeated the same vascular intricacy, adding more and more to the general labyrinth. The interval between any two branches was occasionally very considerable, and in such cases the vessels wended about in a very tortuous manner, as if

profiting by their freedom from lateral ties. Nowhere did a secondary or a tertiary offset anastomose with like branches from a primary vessel. The other vascular source of the rete mirabile, the thoracic aorta, added its supply through the seven intercostal branches which have already been described. They entered the mass along its middle, and thus divided it into symmetrical halves. Though not presenting the same beautiful regularity in their origins, the vascular supply from these aortic branches was in every other respect similar to that from each of the posterior thoracics. They entered the substance of the rete, and were there lost in the intricacies of the plexus.

On unravelling the rete throughout its depth and to the extent of about the breadth of two or three intercostal spaces, the characters and arrangement of its constituent vessels were readily examined. In character and size they were divisible into three sets, easily distinguished from each other. For easier reference I have called them vasa maxima, vasa media, and vasa minima. The first set, vasa maxima, contained vessels of a large calibre, but possessing very thin walls. They were situated chiefly along the middle of the inferior aspect of the rete towards its posterior extent, and more particularly opposite the ninth and tenth intercostal spaces. Their walls were peculiarly puckered so as to give them an appearance somewhat like that of the large intestines. It was due to this puckering that these vessels became so curiously contorted when inflated, causing the whole superficial aspect of the rete to resemble a mass of cerebral convolutions in miniature. After loosening the vasa maxima from their connective tissue, the puckerings still remained, and seemed to be produced by a band or bands running more or less longitudinally in the coats of the vessels. The second set of vessels, vasa media, were smaller than the preceding, though their walls possessed a greater proportionate thickness. They were the most generally distributed throughout the mass, meandered in a very tortuous manner, and presented puckered walls, though less distinctly marked than the preceding. The third set, vasa minima, consisted of vessels very much smaller than the preceding, but having proportionally the thickest walls. Their coats were entirely devoid of the puckering so characteristic of the others, and they were generally

found deeply imbedded in the rete. In their course they were only slightly tortuous. They formed here and there distinctly isolated plexiform areas, easily distinguished from the rest by the straight, narrow, thread-like appearance of their constituent vessels. The anastomoses of each set were continuous with those of the others. The walls of the vasa maxima and media were lax, and the vessels appeared as if empty. This was doubtful in the case of the vasa minima. Occasionally vessels of a size intermediate to those specified were met with, but they were only exceptions.

When compared with its great extent, the branches supplied by the rete mirabile to the structures beneath it were very few. These were chiefly muscular and osseous, and were most distinctly seen on reflection of the central band from the bodies of the vertebræ, or of the lateral masses from the intercostal spaces. From their small and insignificant size, they probably but connected the vascular mass of the rete with nutrient vessels of the surrounding structures. They presented no puckering of their coats. In addition to the preceding, larger branches passed through the vertebral foramina into the spinal canal. They had puckered walls, and were evidently communications between the rete and the vessels within the vertebral canal, or they extended a meshwork of the same character as the rete into that canal.

In unravelling the rete mirabile many structures were found imbedded within its substance, or surrounded by its anastomotic vascular plexus. These were—several veins, the first portion of the intercostal nerves, and the sympathetic ganglia with their branches. Some of the veins were large, all of them had very delicate walls. They seemed to pass towards the spine, and, while in the substance of the rete, they received many branches apparently derived from a very fine network situated within the interspaces and over the coats of the anastomotic arteries. But they were much too small and delicate, and the parts much too decomposed for any satisfactory dissection to be made with the scalpel. The intercostal nerves lay very deeply in the substance of the rete, and while thus covered each received its sympathetic root. The sympathetic ganglia were situated in the vertebral grooves close to the roots of the

transverse processes. They were large, laterally compressed, and irregularly stellate from the number of branches which passed off to all sides, and were closely surrounded by the anastomotic arteries. In addition to their usual branches, they supplied numerous slender offsets traceable for a considerable distance into the substance of the rete. These offsets communicated with each other in a plexiform manner, and each point of connection presented a slight swelling. Whether the latter were cell-bearing centres or mere fibrous thickening of the sheath, remains still for investigation, as in this case the parts were unfit for microscopical examination.

Remarks on the Anatomy of the Rete Mirabile and on its Vascular Sources.

It is very interesting to note that though the distribution of the aortic trunks differs from that of the representative vessels in man, yet the regions supplied by special branches remain the same, the branches to them being derived from other sources. Thus, though no thyroid axis springs from the posterior thoracics, yet its sub-divisions are represented by offsets from neighbouring arteries. I have already described a cervical branch corresponding with the "cervicalis ascendens," which, on the right side, arose from the arch of the posterior thoracic, and on the left from the internal mammary.[1] I may here add that the latter vessel, which itself arises from the common carotid, supplies directly the representative of the inferior thyroid, and indirectly, through its axillary branch, that of the suprascapulars. Again, the posterior thoracics, by their first arched portions, represent the subclavian as the relations they present to neighbouring structures clearly bear out, whilst their costal portions correspond with greatly enlarged and extended superior intercostal branches of the subclavian. Representatives also of the transverse and the deep cervical vessels are given off by the first intercostal group of this second portion of the posterior thoracics.[2] Some of the origins above indicated occur sometimes as varieties in man. Thus, the cervicalis ascendens[3] is

[1] Page 379. [2] Page 379.
[3] *Quain's Anatomy*, 7th ed. vol. i. p. 371.

occasionally derived from the subclavian, and the transversalis cervicis,[1] from the third division or last portion of the arch of the same trunk. As, in the specimen dissected, the axillaries were smaller than the internal mammaries, I have considered them as branches from the latter, and, for the same reasons, the latter as arising from the common carotid. But since writing my notes on the subject, I find that Owen takes a different view of these vessels when speaking of the corresponding trunks in the adult Porpoise. He describes the posterior thoracic as arising from the first trunk of the aortic arch, and adds that the same trunk, after giving off the right carotid, "divides into right brachial and internal mammary arteries."[2] But if any importance be put upon the relative calibres of trunks and their branches, as well as on their relations and distributions, my description accords with what the fœtal Narwhal presented.

From my description of the vessels entering into the formation of the rete mirabile, it is evident that the supply of each half of the mass is about equal,—that is, that about the same number of vessels pass from the costal portion of the posterior thoracic which skirts the outer margin of the rete, as are supplied by the branches from the intercostals of the thoracic aorta. The relation also of the halves of the rete to the heart and aortic system seem to me worthy of particular notice. Each half lies between two arteries, both of which are the sources of its vascular supply. Of these, one, the aorta, is the central trunk of the arterial system, and is common to the right and the left halves. The second source, that is the lateral source, is, on the left side a primary branch, and on the right side a secondary (from the shortness of the innominate equivalent to a primary) branch of the same central trunk. Again, the lateral sources are connected to each other and to the left ventricle by the short span of the aortic arch, whence spring the vessels passing to the head.

As my notes differ very materially from accounts given by Owen and by Breschet of the vessels entering into the formation of the thoracic rete in the Porpoise, Dolphin, &c., it may be as well to point out these discrepancies, that other observers, when opportunity offers, may be led to clear them up. The most

[1] *Quain's Anatomy*, 7th ed. vol. i. p. 373.

[2] Owen's *Comp. Anat. of Vert.* vol. iii. p. 546.

important of these is that Breschet, in his admirable anatomico-physiological monogram on the subject, entirely ignores the very existence of the posterior thoracic arteries. Indeed, when speaking of the manner in which the aortic intercostals become convoluted so as to constitute the plexus, he goes on to say, "Nevertheless branches representing the intercostal arteries are seen issuing from the outer border of this plexus at points corresponding with the intercostal spaces, but these are of less calibre than the artery seen entering the inner border."[1] He evidently means that the aortic intercostals break up into the meshwork, and then from the meshwork some branches uniting pass out to supply the place of intercostal arteries. I have pointed out that the three last, or rather more correctly, the last two but one of the aortic intercostals do enter the mass of the rete, and after *giving off minute* and *numerous branches to it* pass out as intercostals.[2] But they do not represent the intercostals of Breschet, which are not branches directly from the aorta, but directly from the rete. On the other hand, Owen describes the posterior thoracic as simply bending down and supplying "the five anterior intercostal spaces. The succeeding ones derive their arteries," he adds, "directly from the thoracic aorta, and some of them by a short trunk which bifurcates."[3] He states the supply of intercostals from this vessel, but omits the important part it plays in the formation of the rete. The reason for these discrepancies may be perhaps explained by the fact that these trunks were so embedded in the mass of the rete as to escape observation altogether in the case of Breschet and partly in that of Owen. I am very much inclined to that supposition from the fact that in one of his plates Breschet figures an arterial branch as dipping into the substance of the rete, and he refers it to "a branch coming from the subclavian arteries, similar to those passing from the aorta and inclining from above downwards towards the plexus to contribute to its formation."[4] But he does not refer to it in any way in the text, nor does he mention that it supplies any intercostals, even though he says that John Hunter described this plexus as being formed by the

[1] *Hist. Anat. et Phys. d'un organe de nature vasculaire découvert dans Cetacés*, par. M. G. Breschet, Paris, 1836, chap. 2, sect. 19, p. 18.

[2] Pages 381, 382. [3] *Loc. cit.* vol. iii. p. 546. [4] *Loc. cit.* pl. ii. T

intercostals and the subclavian.[1] John Hunter's words are: "The subclavian artery in the piked whale, before it passes over the first rib, sends down into the chest arteries, which assist in forming the plexus on the inside of the ribs.[2] Here again there seems to be some differences in the arrangement of the vessels. This branch described by Hunter does not seem to give off any intercostals. Still, it is evident that in the piked whale there is a true subclavian continuing over the first rib (I presume) to become axillary. It is also clear that there are no posterior thoracics described by Hunter; in other words, I am quite entitled to call the first portion of the posterior thoracics a subclavian, as I am to recognise in its costal continuation an exaggerated superior intercostal. I adopted the term "posterior thoracic" after finding that Owen had used it, as by that means confusion is obviated. In my notes I did not feel justified in calling the whole vessel subclavian, and had, therefore, given it the name of intrathoracic. It may seem improbable that the formation of the thoracic rete in the Narwhal should differ so materially from that in the Porpoise and other Cetacea, and yet so it appears to be. The next discrepancy has reference to the aortic intercostals. From Owen's description it is evident that in the Porpoise there are more true aortic intercostals (that is, intercostals passing to the spaces) than in the Narwhal, because he describes the posterior thoracics as supplying only the five anterior spaces. And in his account of these aortic intercostals he says that they "send off the dorsal branch, and that which accompanies the ribs; but they also, and chiefly, divide into a vast number of branches"[3] forming the rete. I have carefully described these branches of the thoracic aorta, and it may be remembered that, of the first four, one corresponded with the fourth and fifth interspaces; the other four represented respectively the succeeding spaces from the fifth to the eighth, and none of these supplied true intercostals. Further, the others representing true intercostals distributed their branches alternately to left and right, and

[1] *Loc. cit.* chap. 8, p. 43.

[2] "Observation on the Structure and Economy of Whales," by John Hunter, *Phil. Trans.* 1787, p. 415.

[3] *Loc. cit.* p. 456.

each furnished offsets to more than one space. Again, the first four entirely broke up into branches for the rete, whereas the others *supplied* to the rete minute offsets, having characters similar to those given off from the posterior thoracics.[1] The passage quoted may mean this difference, but it does not appear clear. Breschet's remarks correspond with mine; he describes them all as having single origins, but afterwards bifurcating, which fact does not accord with Owen's observations. Breschet, however, makes all the intercostals as passing from branches derived from the outer margin of the rete. Hunter mentions that the intercostals "divide into a vast number of branches which run in a serpentine course between the pleura, ribs and their muscles. . . . Those vessels," he adds, "everywhere line the sides of the thorax," &c. He evidently observed the rete to cover the whole of the thoracic walls, for further on he remarks, when speaking of the piked whale, "I am not certain but the internal mammary arteries contribute to form the anterior part of this plexus."[2] This description differs markedly from the arrangement I have just given, as seen in the Narwhal. The third discrepancy, I should like to point out, pertains to the constituent vessels of the rete. Owen describes the mass of these vessels as "a close tortuous interlacement," unfortunately omitting the complete characteristically anastomotic nature of the meshwork. Further on he adds, "Any convoluted intercostal artery contributing to this reservoir can be unravelled and traced to a *great length, without sending off branches or changing its calibre.*"[3] Breschet is very minute and very full in his description of the numerous prolongations, which the mass sends in various directions, particularly into the spinal canal. But in his remarks on the arrangement of the vessels he holds that they are "seen *to retain almost the same calibre, since there are scarcely any secondary branches furnished by these vessels.* There is no successive decrease of calibre in these arteries, and they can be followed throughout their extent without the anatomist being checked in his investigations, either by their passing into capillaries or penetrating parenchymatous tissue."[4] Breschet,

[1] Pages 381, 382.
[2] *Loc. cit.* p. 415.
[3] *Loc. cit.* p. 546.
[4] *Loc. cit.* chap. 2, sect. 19, pp. 17, 18.

by these remarks, has for his main object the establishment as a fact that the rete is purely arterial and *suo ipso* in character. Hunter, we have seen, found them simply to "run in a serpentine course, making a thick substance somewhat similar to that formed by the spermatic artery in the Bull.[1] Again, it is evident from these three anatomists' descriptions that there must be a great difference between the Narwhal on the one hand, and the Porpoise and other Cetacea on the other. In the latter, it would seem, there is no network worth naming, the mass being mainly due to extensive convolutions of the vessels, and the vessels themselves present no sudden enlargement in their calibre, nor puckerings in their coats, nor that minuteness and exquisitely curious equality in calibre at their origin. There seems to be also an absence of difference of size, and this is important to bear in mind, because this difference in size may have a weighty teleological meaning.

Breschet, in his memoirs, lays great stress on the fact that the intercostal veins do not form intrathoracic, but intraspinal azygos trunks, the latter having the same inequality in size noticeable in the usual arrangement of these veins.[2] Unfortunately I did not read Breschet's description until many years after I had written my notes, and then I could not refer to any of my dissections, so as to ascertain whether in this the Narwhal resembled other Cetacea. However, it may be remembered that in my notes I describe having seen some large veins imbedded in the substance of the rete and passing towards the spine.[3] Undoubtedly these were Breschet's intercostals. However, veins corresponding with posterior thoracics received intercostal branches, representing the arterial offsets sent to those spaces. Were such the case in the Porpoise, then the intraspinal azygos veins would suffer great diminution in size. The minute venous plexus described as passing from the coats of the constituent vessels of the rete to these large veins, may represent the veins corresponding with the anastomotic areas found in connection with the vasa minima.[4]

Teleological deductions.—It seems to me that the Cetacea present all the various forms of retia found in other classes of

[1] *Loc. cit.* p. 415.
[2] *Ibid.* chap. 2, sects. 21, 22, pp. 18, 19.
[3] Page 386.
[4] Pages 385, 386.

vertebrata. A cursory examination into these would at once strike the observer that all cannot have the same function to perform in the economy of the animal. Again, in running over the long list of animals possessing retia, another fact presents itself, namely, that they are not limited only to animals of similar economy. Animals remarkable, some for the slowness and others for the power and rapidity of their movements,—cold-blooded and hot-blooded animals,—all present in some form these retia. The Cetacea alone, however, possess that form at once so characteristic and singular. I have pointed out that this form is remarkable for the minuteness and equality of calibre of the constituent vessels at their origins, for the sudden enlargement of some of these vessels, at the expense of the thickness of their coats, and for the peculiar puckerings presented by their walls.[1] If all these characters be not found in the thoracic rete of all Cetacea, it is certain that they are present in the well-advanced fœtal Narwhal. This form of retia I would propose to call the *bilateral*, *i.e.*, possessing two margins, each bounded by the sources of its vascular supply. In contradistinction I would term *axial* those retia found in the course of any vessel. The axial might conveniently be divided into, first, *mediate*, in cases where, after breaking up into the rete, the meshwork again coalesces so as to *continue* the same arterial trunk onwards as before; and, secondly, *terminal*, where the artery breaks up into slender anastomotic branches which do not reunite. Again, these two forms *mediate* and *terminal* might each be further subdivided into *complete* and *incomplete*, the former indicating a complete breaking up of the whole trunk, and the latter, a partial division, the trunk more or less diminished in size, continuing through the meshwork formed by the branches it has supplied, this meshwork or anastomosing vessels closely investing it. The axial form of retia would seem sometimes to have as its object the supply of arterial blood by a single large trunk, sometimes the avoidance of a single vessel, where compression of it, in any particular condition of the animal, might prove injurious to the parts thus nourished. In other cases it would appear to indicate a means by which sudden pressure upon important organs is checked. Some have sup-

[1] Page 385.

posed that in a few instances this form of rete may act as a modified lymphatic gland in which a chemical change may take place in the blood before it passes to certain organs.[1] The Narwhal is rich in specimens of *complete terminal* form of the *axial* rete. Many large branches as they pass underneath or towards a muscle are seen suddenly to break up into a leash of elongated slender plexiform vessels, which constitute the nutrient vessels of the muscle (Plate XXII. *B*). In such cases one may presume that, by such means, one vessel is capable of conducting to the muscles a large amount of blood, at the same time that, by its sudden subdivision into much smaller offsets, at a certain part of its extent, it prevents pressure from contraction of the muscle interfering with its function. The arrangement of the arteries in the arm and leg of the Sloth and Loris would also indicate avoidance of compression. As a means to prevent undue pressure upon important organs, there is no better example than the axial rete on the internal carotids of the Ruminantia. One of the cases in which its glandular function was insisted, is the axial rete on the common carotids of the Batrachia.[2] But this last seems to me very improbable, as no glandular structure surrounds these retia. There is an *incomplete terminal* form of *axial* rete, which I found enveloping the caudal artery from the eighth to the eleventh hæmal arch. I could not, in my specimen, ascertain whether it was arterial or venous, but subsequently I read Owen's description of a similar arrangement in the Porpoise, and he describes it as arterial.[3] In the Museum of the Royal College of Surgeons, Professor Flower showed me a section of the same artery of a whale with a similar rete. It is difficult to suggest the probable function of this rete. It may have to do with the nutrition of the caudal muscles, or with the avoidance of compression of the arterial trunk during the movements of this part of the tail; for it seems to occupy what would appear to be the most movable part of the tail.

The "bilateral" rete is found, as far as I know, only in the Cetacea, and has relation evidently to the power these verte-

[1] See Breschet's Monogram as cited above, chap. 6, sects. 34, 35, pp. 30–34; also his notes and quotations.

[2] Breschet's Monogram, pp. 30, 31.

[3] *Loc cit.* p. 547.

brates possess of diving into deep water, and remaining below the surface for so long a time without the need of respiring. Breschet in his monogram has entered very fully into this question. He acknowledges this form of rete to act as a diverticulum, but he at the same time asserts it to be a diverticulum not to annul pressure,—not to serve as a safety-valve,—but to store up a large quantity of oxygenated blood, which may be restored gradually to the circulation during the cessation of the respiratory function.[1] He further points out that the greatest amount of healthy blood being required by the caudal extremity, which is a powerful weapon both for attack and defence, the rete mirabile is situated in the thorax, and is connected with the arterial trunk directed backwards towards the tail. He presumes, also, the "axial" rete on the common carotid of Batrachia to possess the same function. I have already pointed out that the thoracic rete has a remarkable central position; and, therefore, whatever its function, the blood it contains flows rapidly to the heart, as well as backwards and forwards throughout the body.[2] Breschet does not deny that the brain and spinal cord require oxygenated blood, and he points out that the prolongations of the rete into the canal, and its extension along the neck to the base of the cranium is to ensure that. But should the rete, when full, empty itself, it will at once supply blood to the encephalon as well as to the spinal cord. Breschet explains the process of emptying the rete to be effected, partly by the resiliency of the constituent vessels, and mainly by the pressure exerted by the inflated lungs (he asserting that before plunging the Cetacea always inflate their lungs).[3] The latter, he adds, also "fixes the chest for the muscles to act from."[4] There is no doubt that such must be most probably one of the functions of the thoracic rete, but from the central position of the rete, and owing to the fact that other diving vertebrates present nothing analogous in structure, I am inclined to believe there must be certain conditions in which the heart, vessels, and nerve centres in Cetacea are under pressure, which would prove fatal but for such a diverticulum, though it is difficult to conjecture one. It

[1] See Monogram, the whole of sect. 43 (chap. 8), especially pp. 64–71; also "conclusions" immediately following.

[2] Page 388. [3] *Loc. cit.* chap. 8, sect. 43, p. 67. [4] *Ibid.*

is easily understood now why the vessels entering into the formation of the rete should be minute and of equal calibres, also why they should pass directly or almost directly from large trunks. Once the blood is in the rete it is equivalent to being out of the circulation. The filling or emptying of such a vast diverticulum would prove dangerous in the extreme were it done suddenly by means of large branches, branches, for example, of the size of the vasa maxima. By this means, however, the blood pours in or out as through a fine sieve. Then, again, to fill such an extensive reservoir from vessels at some distance from the central trunk would be simply impossible, as the great numbers of offsets needed would interfere with the adequacy of the vessels to supply nutritive branches. Besides, supposing oxygenated blood to be dealt out by this diverticulum, its position is such that the most important parts of the animal are at once supplied with what it needs, and supposing pressure to be present to an injurious extent the same parts will be as speedily relieved. It seems also easily explained why the small vessels at their origins should be much thicker than at their enlargements. It is very probably that a comparatively dense coat of circular non-striated muscle may be present to act as a sphincter, and retain the blood in the meshwork once it has entered. It is difficult to divine a reason for the puckerings in the vasa maxima and media. It may perhaps be for the purpose of strengthening the already attenuated coats of the vessels, as by that means pressure is isolated to small circumscribed areas. As the vasa minima were apparently filled in fœtal life, one would infer that they were the nutrient vessels of the rete. This supposition seems to me strengthened by the fact that the nutrient muscular and osseous vessels, passing from the rete, bore characters similar to the vasa minima, and most probably connected other nutrient vessels with the anastomotic areas of the latter. Thus, these vasa minima would have a separate connection with the systemic arteries, sufficient to supply them constantly with oxygenated blood, even should the vasa maxima and media be inactive and empty, at certain times, which the above would lead one to infer. Besides, there seems to be every probability that the fine venous plexus described

at page 386, may return the blood to the systemic veins after it has performed its nutritive function.

The retia found in connection with the venous system are even more numerous than those found in relation with the arterial. There is not, however, such a variety, and they range in form from the simple network to large and extensive lacunar arrangements, the constituent vessels having very delicate walls.[1] I conclude my remarks with a summary of the vessels described, as well as of the terms I have proposed for distinguishing, by name, the various forms of retia.

Summary.—The THORACIC RETE MIRABILE is formed by vascular supplies from the posterior thoracics (costal portion), as well as their intercostal branches, and the intercostal branches of the thoracic aorta. It communicates directly towards the abdomen, with the first lumbars and accessory lumbars of the abdominal aorta; towards the neck with the ascending cervical of the posterior thoracic on the right side, and of the internal mammary on the left, and through it, with the anterior thyroid and pharyngeal of the external carotid; along the spine with the vessels of the spinal cord. Its constituent vessels are three, distinguished by their calibres, and termed vasa maxima, vasa media, vasa minima, all continuous with each other.

The RETIA MIRABILIA are arterial and venous.

The arterial are bilateral, having two margins, each bounded by the sources of its vascular supply; *axial*, occurring in the course of any artery; *terminal*, constituent branches do not reunite; *complete*, no continuation, through rete, of any part of parent trunk; *incomplete*, continuation of central part of trunk through substance of rete; *mediate*, constituent branches reuniting and continuing parent trunk onwards; *complete*, as above; *incomplete*, do.

[1] Vast venous plexuses are found in the Cetacea, and if one could prove that the rete has the function of supplying oxygenated blood during the immersion of the animal, then such a quasi-lacunary plexus would be absolutely necessary to store up the carbonised blood until the animal could again respire. Such plexuses are present, and greatly support this supposition as to the function of the rete.

EXPLANATION OF PLATES.

Plate XXII.

A. Heart, aortic arch and its branches, of the Narwhal (reduced from nature); 1, innominate artery; 2, right common carotid; 3, r. posterior thoracic; 4. cervical branch corresponding with "r. cervicalis ascendens;" 6, first group of intercostals; 7, 7, &c., other intercostal groups. The whole of the costal portions of the posterior thoracics are seen to be clothed with minute branches which pass to the rete mirabile. 8, cervical portion of r. internal mammary; 9, r. posterior (inferior) thyroids; 10, group of muscular branches to right cervical muscles; 11, r. axillary artery; 12, r. external carotid. The number also points to the anterior (superior) thyroid artery. 13, r. internal carotid; 14, 14, &c. muscular branch to muscles of posterior, lateral and anterior aspect of neck; 15, r. pharyngeal branch; 16, r. laryngeal branch; 17, r. occipital artery; 18, r. lingual artery. The accented figures refer to corresponding vessels on left side.

B. Sketch illustrating the character of the elongated plexiform arrangement generally presented by arterial branches when passing beneath or towards muscles—taken from a branch of internal mammary passing between the pectorals (reduced).

C. Sketch illustrating the manner in which large arteries supply considerable offsets which, reuniting, constitute a single trunk—taken from left internal mammary. 1, left internal mammary; 2, left ascending cervical; 3, left axillary artery.

Plate XXIII.

Diagram intended to show position of rete to its vascular sources, also relations of rete and its sources to ribs, intercostal spaces, and each other (less than one-third natural size). The ribs are represented partly by lines and partly by dots. That portion dotted denotes the part covered by the rete. The dotted lines external to the ribs represent costal cartilages. The thoracic aorta is represented as removed. The vessels in the mesial line of the rete are the intercostal branches of the thoracic aorta. The trunks skirting the mass of the rete on each side are the costal portions of the "posterior thoracics." On its outer side are seen its intercostal groups, the first of which on the left side is intra-thoracic. 12, Intra-thoracic portion of internal mammary; 13, its sternal branch; 14, its thymic offset; 15, its anterior (superior) epigastric; 16, its musculo phrenic.

OBSERVATIONS ON THE CORONARY VEINS OF THE STOMACH. By W. J. WALSHAM, F.R.C.S., *Demonstrator of Anatomy and of Operative Surgery at St Bartholomew's Hospital; Surgeon to the Metropolitan Free Hospital and Royal Hospital for Diseases of the Chest.* (PLATE XXIV.)

VERY meagre descriptions of the veins of the stomach are given in most of the text-books on anatomy. The descriptions in some are confused; in all they are inaccurate or incomplete. The inaccuracy, however, to which I particularly wish to call attention is in the description of the veins that return the blood from the lesser curvature of the stomach—an inaccuracy which is found, not only in the text-books on anatomy, but also in the larger works that I have had an opportunity of consulting. Now, whereas there are two veins running along the lesser curvature of the stomach, and one of them of very considerable size, the works, reference to which is given below, agree in describing but one, and that, moreover, is said to be small. The larger of the two veins, which I have always found to be present, begins near the pyloric end, and runs in a direction from right to left. The single small vein of the books—variously called the coronary, the gastric, the superior coronary, and the pyloric—is said to begin at the cardiac end, and to run from left to right.

Thus in Quain[1] we read: "The coronary vein of the stomach lies parallel with the artery of the same name. Its size is inconsiderable, and its direction transverse from the cardiac to the pyloric end of the stomach along the small curvature. On reaching the latter point it turns downwards and opens into the trunk of the vena portæ." The vein taking this course is figured in the "view of the principal branches of the vena portæ" (fig. 319).

In Gray[2] it is said "that the gastric is a vein of small size, which accompanies the gastric artery from left to right along the lesser curvature of the stomach, and terminates in the vena portæ." A drawing (fig. 250) is given of a vein taking such a course. In this diagram also the right gastro-epiploic vein is called the left gastro-epiploic, but is represented opening into the superior mesenteric in the normal manner.

[1] *Quain's Anatomy*, by Drs Sharpey, Thomson, and Schäfer, 8th edition, vol. i. p. 501.

[2] *Anatomy, Descriptive and Surgical*, by Henry Gray, 8th edition, edited by T. Holmes, p. 448.

This mistake is evidently one of the engraver's, as the left vein is said in the text to open into the splenic.

Ellis, in the last edition of his *Demonstrations of Anatomy*,[1] gives a drawing from Henle, and remarks: "The superior coronary vein, 144*f*" (referring to the drawing) lies along the upper border of the stomach. It begins in the œsophagus and the left part of the stomach, and joins the vena portæ at the pylorus."

In Holden's and in Heath's Anatomy these veins are not mentioned.

In Turner's introduction to Human Anatomy[2] there is a diagram of the portal venous system, in which a vein is depicted as running along the lesser curvature of the stomach from left to right, and gradually increasing in size as it approaches the pylorus, where it is represented as opening into the portal trunk. The right gastroepiploic vein is also delineated as openingi nto the trunk of the portal just above the union of the superior mesenteric and splenic veins. In the text it is stated that "The coronary vein runs along the small curvature of the stomach, and joins the portal venous trunk near its origin."

In the *Cyclopedia of Anatomy and Physiology*[3] no further account is found than that "the gastric veins, of which the coronary is the most considerable, end in the splenic."

The inaccuracy in the description of these veins is not confined to the English works on anatomy; it is also to be found in the French and German. Thus in Hyrtl[4] we read: "The vena gastrica superior runs in the lesser curvature from left to right into the trunk of the vena portæ, and receives the blood from the upper stomach walls from the cardia to the pylorus, and from the superior transverse portion of the duodenum."

Krause[5] says: "The vena coronara ventriculi runs from left to right on the lesser curvature of the stomach and behind the superior horizontal part of the duodenum. It receives the veins from the cardia, and communicates by small œsophageal veins with the vena azygos and vena hemiazygos. It further receives veins from the upper part of the stomach walls and from the above-mentioned portion of the duodenum."

Cruveilhier[6] and Sappey[7] do not describe the course of the veins of the stomach, but content themselves with saying that they follow the course of the corresponding arteries.

Beaunis and Bouchard[8] do not refer to the veins of the stomach

[1] *Demonstrations of Anatomy*, by George Viner Ellis, 8th edition, 1878, p. 488.

[2] *An Introduction to Human Anatomy*, including the Anatomy of the Tissues, by William Turner, p. 523.

[3] *Cyclopedia of Anatomy and Physiology*, edited by Robert B. Todd, 1849–52.

[4] *Lehrbuch der Anatomie des Menschen*, von Joseph Hyrtl, 11th edition, 1870, p. 955.

[5] *Handbuch der Menschlichen Anatomie*, von Krause, vol. ii. 1879.

[6] *Traité d'anatomie descriptive*, par Jean Cruveilhier, 1871, vol. iii. p. 237.

[7] *Traité d'anatomie descriptive*, par Sappey, 1879, vol. ii. p. 734.

[8] *Nouveaux Eléments Anatomiques Descriptives*, par H. Beaunis et A. Bouchard.

separately; but in their brief account of the splenic vein, say, "The coronary vein of the stomach often opens into it, but at other times enters into the portal vein." In describing the portal vein they say, "It receives in its course the pyloric vein, and higher up the cystic vein;" but they do not here mention the coronary vein as opening into it.

I have for some years been accustomed to teach and demonstrate an arrangement of these veins different from that in the works just quoted. It was not until one of my pupils pointed out to me last session that my teaching did not correspond with the account in his text-book, that I became aware how generally this inaccuracy in the description of the coronary veins had crept into the works on anatomy. Since my attention was drawn to the subject I have made a point of looking at these parts in each body that has come into the dissecting rooms; and I have in six or eight instances injected the portal system of veins with wax and had it carefully dissected. The arrangement invariably found was that which I have been accustomed to teach, and which is shown in the accompanying drawing made for me by Mr Godard from the dissected part. In all instances there were two veins along the lesser curvature, a larger one, running from right to left, from the pyloric towards the cardiac end and roughly corresponding in direction to the gastric artery, and a smaller one proceeding from left to right towards the pylorus in relation with the pyloric artery (Plate XXIV.). This latter is apparently the vein which is described in the works quoted as the coronary, gastric vein, &c. The larger vein, which from its position is more difficult to dissect, seems to have been overlooked; it seldom, as far as my observation goes, contains any blood, and is generally cut away by the student without having been seen unless his attention is specially drawn to it. It usually begins in three or four large branches near the pylorus, one of which anastomoses with the pyloric vein; it then runs from right to left along the lesser curvature, receiving in its course branches from the anterior and posterior surfaces of the stomach; and about an inch to an inch and a half from the œsophagus it leaves the lesser curvature, winds backwards, downwards, and to the right between the layers of the lesser omentum at some distance from the upper curve of the stomach, following somewhat the course of the gastric artery, and terminates, after passing

over the splenic artery, in the portal vein. When moderately distended with injection it measures about an eighth of an inch in diameter. At the spot where it changes its direction it receives several large branches from the cardiac end of the stomach, and a few smaller ones from the œsophagus. It is also joined in its course through the lesser omentum by one or two venules from the peritoneum. When the injection has been successful, a few small veins may be seen to emerge from the substance of the liver, to cross the coronary vein where it lies between the layers of the lesser omentum, and to join the same vein before it leaves the lesser curvature of the stomach.

The pyloric vein, *i.e.*, the smaller of the two veins of the lesser curve, is of inconsiderable size, and appears to be the one described in the books under the various names of coronary, gastric, &c. It runs from left to right along the pyloric end of the lesser curvature, receives veins from the pylorus and duodenum, and terminates in the portal trunk below the opening of the coronary vein. In place of a single vein in this situation I have frequently observed several small ones, which open into the portal trunk either separately or else after converging into a very short single stem.

The veins along the greater curvature of the stomach are generally fairly accurately described. They correspond in their general direction to the arteries which they accompany. The right gastro-epiploic terminates in the superior mesenteric. It receives large branches from the anterior and posterior surfaces of the stomach and from the epiploon. The left gastro-epiploic terminates in the splenic about three-quarters of an inch after the union of the main branches of the latter; it receives tributaries from the anterior and posterior walls of the stomach and epiploon, and just before its entrance into the splenic vein a large branch from the greater end of the stomach. In size these two—right and left epiploic veins—bear an inverse proportion to one another: when one is large the other is small, and *vice versa*. The rest of the blood from the upper part of the cardiac end, and from the lower part of the œsophagus, is generally returned by two or three large veins, which open usually by a common trunk into one of the upper main radicals of the splenic vein.

Although I have not found an accurate description of the coronary veins in any of the works I have had an opportunity of consulting, I do not doubt but that they have often been correctly observed and described. Without laying any claim, therefore, to having been the first to point out their normal arrangement, I venture to send these observations to the *Journal of Anatomy and Physiology*, not because they are of any practical importance, but because it seemed to me, as a teacher of anatomy, worth while to call attention to an inaccuracy which appears to be general.

EXPLANATION OF PLATE XXIV.

1. Coronary vein. 2. Pyloric vein. 3. Right gastro-epiploic vein. 4. Left gastro-epiploic vein. 5. Portal vein.

Note on Mr Walsham's Observations on the Coronary Veins of the Stomach. By Professor TURNER, M.B., F.R.S.

Since receiving for publication Mr Walsham's paper, I have examined, with especial reference to the question raised by him, a subject in which I had injected the portal system of veins. In this specimen the coronary vein was of considerable size and corresponded generally in position with the arteria coronaria ventriculi. It commenced a little to the left of the pyloric end of the lesser curvature, and extended along this curvature to the region of the œsophageal opening, when it inclined to the right for about two inches and joined the portal venous trunk. In its course it received veins from both the anterior and posterior walls of the stomach, and just before it left the lesser curvature a large vein from the anterior wall of the cardiac end of the stomach, the course of which was from left to right.

A much smaller vein was in relation to the pyloric artery at the pyloric end of the lesser curvature. It freely communicated with one of the rootlets of the coronary vein; but, instead of

opening into the portal venous trunk near the opening of the coronary vein, it passed independently almost parallel, and immediately to the right of the portal venous trunk, to enter the substance of the liver at the transverse fissure. With the exception of the mode of termination of the pyloric vein, which is without doubt an individual peculiarity, this dissection confirms Mr Walsham's description of the course of the veins of the lesser curvature of the stomach.

As regards the mode of describing the veins of the curvatures of the stomach, I would, however, suggest that it is better to avoid the expressions from left to right and from right to left, inasmuch as the curvatures can not be regarded as transverse in direction, but as approaching in at least a large part of their extent to the vertical plane. As has been pointed out, both by Luschka and myself, the stomach lies "for the most part vertically in the left hypochondrium, so that the fundus is the uppermost part of the organ; whilst the pylorus, which curves to the right into the epigastrium, forms its lower extremity."

ON A COMMUNICATION BETWEEN THE AIR-BLADDER AND THE CLOACA IN THE HERRING.

By F. W. BENNETT (*from the Zoological Laboratory, Owens College, Manchester*).

THE common Herring possesses an extremely long air-bladder. It stretches forwards to the head, and its anterior termination is near the labyrinth of the auditory organs. About the middle of its length it is connected by a duct with the stomach. The stomach (*s*) is capacious and elongated; the commencement of the mid-gut is near the gullet; however, the stomach is not a simple *cul-de-sac*, but becomes continuous posteriorly with the ductus pneumaticus (*p*).

But there exists another communication between the bladder and the exterior, which seems not to have been noticed elsewhere. Although the herring is so common, observers seem quite to have overlooked the existence in it of a communication between the air-bladder and the cloaca.

Stannius[1] gives a full description of the various modifications of the air-bladder in fishes; indeed, he refers several times to the herring, but fails to mention this connection. In Professor Owens' *Anatomy of the Vertebrata*,[2] and in Gegenbaur's *Comparative Anatomy*,[3] figures of the herring are given, copied from Brandt and Ratzeburg's *Medizinische Zoologie*, 1833. In these figures the bladder is represented as running backwards towards the cloaca, but the dissection from which the figures were taken was not carried far enough back to show the connection between the two.

This communication can readily be seen if the left side of the fish be carefully removed as is represented in the woodcut.

The arrangement here shown is the normal one, and existed in all of twenty-five specimens examined. Till within one-half inch of the cloaca, the air-bladder (*e*) retains its beautiful silvery appearance; this suddenly ceases, and the remainder is muscular, so that it is only with difficulty that it can be distinguished from the surrounding structures.

[1] *Handbuch der Zootomie*, by Siebold and Stannius, 2d edition, p. 220.

[2] Vol. i. p. 421.

[3] P. 610. English translation.

anterior branches of the sacral nerves were seen to be arranged in the usual manner. The nerve of supply for the curvator coccygis was given off from the descending branch of the fourth as the latter passed down to communicate with the fifth sacral nerve. The muscular nerve was traced downward between the curvator coccygis in front and the levator ani behind, and terminated by breaking up into a number of small fibrils which entered the former.

The ischio-coccygeus muscle of each side was developed to a greater extent than usual. Its origin was not confined to the ischial spine, but extended upwards as high as the brim of the pelvis, the additional fibres taking attachment to the pelvic fascia covering the obturator internus muscle. None of the fibres of the ischio-coccygeus were inserted into the coccyx, but passed exclusively to the anterior surface of the lateral mass of the sacrum extending from the fourth sacral foramen downward to the sacrococcygeal articulation. The levatores ani, on the other hand, had a more extensive insertion than usual into the coccygeal vertebræ, being attached to the whole length of this segment of the vertebral column. Otherwise, these muscles did not present any deviation from the usual arrangement. The sphincter ani externus was attached in the usual manner to the tip of the

coccyx, but none of its fibres were continuous with those of the curvatores coccygis.

With regard to the action of the curvatores, it is evident that, contracting simultaneously, they would in the first place flex the coccyx upon the sacrum, and in the second they would flex the coccygeal bones upon one another. In carrying out these actions the muscles would co-operate with those fibres of the levatores ani which were inserted into the coccyx. In a subject in which the ischio-coccygei muscles have their usual insertion, the curvatores would co-operate with them rather than with the levatores ani.

The curvatores coccygis of the human subject are the representatives in man of the sacro-coccygei inferiores or depressores caudæ of the lower mammals. Among the latter these muscles are all but constantly present, and in those of them in which the tail is largely developed, and more especially in those in which that organ is functionally of use as a prehensile organ, as in the genera *Ateles* and *Cebus*, the muscles attain to a large size. In the anthropoid apes, on the other hand, in which the tail is reduced to a minimum, these muscles, according to Huxley,[1]—and his observations I can corroborate in respect of the chimpanzee (*Troglodytes niger*),—are entirely absent. This also is normally the case in the human subject.

I have remarked that these muscles are normally absent in the human subject, and this leads to a consideration of the statements of various anatomists with regard to this point. The earliest, and indeed the only definite observation with regard to the frequency of their occurrence in man which I have been able to find, occurs in the writings of Albinus[2] (1734). He says: "Fuerunt, quibus ab utroque latere musculus parvus, oblongus, angustus, tenuis, majorem partem tendineus, gemino capite incipiebat, altero ab interiore et eadem inferiore et laterali parte corporis imi ossis sacri; altero, quod in alio bifidum, ab interiore eademque laterali coccygis primi; descendensque, tribus extremis definebat ad eandem partem coccygis ossiculi secundi, tertii, quarti, præcipue quarti, extremo insigniore, tendineo, quo dexter cum sinistro conjunctus erat. Curvatorem appelare libuit

[1] *Med. Times and Gazette*, 1864, vol. ii. p. 40.
[2] *Historiæ Musculorum*, p. 336.

quoniam coccygem curvat: curvat autem in priora. *Inveni eum in tribus:* in alio imperfectionem et degenerantem; in aliis non musculo, sed ligamento simile." From this it would appear, although his meaning is somewhat obscure, that Albinus had found the muscles to be well developed in *three* subjects, whilst in others they were replaced by ligamentous or tendinous fibres. He gives no reference to the writings of any previous anatomist who had described the muscles under consideration; and inasmuch as he never fails to do so in respect of other muscles referred to by his predecessors, we may, I think, conclude that Albinus was the first to observe and describe the curvatores coccygis of the human subject. Strange to say, they are not figured in the *Tabula musculorum* of Albinus.

Sandifort[1] (1783) merely repeats verbatim the observations of Albinus.

Sömmerring[2] (1794), describing the curvatores coccygis, says: "Ab interna, inferiore et laterali parte corporis imi ossis sacri, et ab interna, et laterali parte ossis primi coccygis ortus, oblongus, exilis, tenuis, plurimam partem tendineus descendit, ut tribus caudis parti laterali secundi, tertii, præsertim verro quarti ossis coccygis, dextro musculo et sinistro inter se ibi conjunctis, inseratur." This is evidently a revised edition of the observations above quoted from Albinus.

Meckel[3] says: "Die curvatores coccygis sind *ungewöhnliche*, kleine, meistens wo sie vorhanden sind, auf beiden seiten vorkommende, längliche, dünne, groszentheils sehnige Bündel, welche von der vordern Fläche des letzten Heiligbeinwirbels und des ersten Steiszbeinwirbels entspringen und sich mit mehrern Zipfeln an die vordere Fläche der untern Steiszbeine heften, wo der rechte und linke gewöhnlich zusammenfliessen." From this quotation it will be seen that Meckel talks of the presence of the curvatores coccygis as *unusual* in the human subject. At the same time, he does not, more than the authors above mentioned, give any exact account, based on his own observations, of the frequency of occurrence of these muscles in man, and for

[1] *Exercitationes Academicæ*, Lug. Batav. lib. i. p. 89.
[2] *De Corporis Humani Fabrica*, tom. ii. p. 212.
[3] *Handbuch der Menschlichen Anatomie*, Band ii. p. 478.

aught contained in the text to the contrary, his remarks may well have been borrowed from Albinus.

Cloquet[1] (1822), when describing the ischio-coccygeus muscle, remarks: "*Souvent* il reçoit de la partie inférieure du sacrum un petit trousseau (*M. curvator coccygis*, Sömm.) mince, grêle, descendant sur le milieu du coccyx, et s'unissant aux deux muscles de droite et de gauche à la fois." From the words employed in describing the muscles, as well as from the reference, it would appear that Cloquet had borrowed his description from Sömmerring. At the same time it is to be observed that, according to Cloquet, the curvatores are frequently (*souvent*) found in the human subject—a statement for which Sömmerring is *not* responsible.

Günther[2] (1844) appears to have himself observed the muscles in question, seeing that they are twice figured in his Atlas and "*nach der Natur gezeichnet.*" He does not, however, make any remark with regard to their frequency of occurrence. In fact, he appears to regard them as normally present.

Von Behr[3] (1846) likewise describes them as if they were constantly present in the human subject.

Theile[4] (1844) refers to the plates of Günther, whilst Cruveilhier[5] (1852) contents himself with a reference to Sömmerring. Neither Henle[6] nor Sappey,[7] in their standard text-books, make any mention of the curvatores coccygis as occurring in man.

Macalister[8] (1875), judging from his catalogue of muscular variations, does not himself appear to have met with these muscles, but refers to the descriptions of Morgagni,[9] Sandifort, and Von Behr. Morgagni, however, does *not* describe them, and the observations of the other authors have been already quoted.

If now we analyse these various statements, we find that Sandifort, Sömmerring, Meckel, and Cloquet have all derived their information directly or indirectly from Albinus, and that

[1] *Traité d'anatomie descriptive*, vol. i. p. 462.
[2] *Chirurgische Anatomie*, tab. 34, i. 6 ; tab. 31, iii. 6.
[3] *Handbook of Human Anatomy*, translated by Birkett.
[4] *Encyclopedie Anatomique*, tom. iii. p. 360.
[5] *Traité d'anatomie*, tom. iii. p. 666.
[6] *Handbuch der Anatomie.*
[7] *Traité d'anatomie descriptive.*
[8] *Trans. Roy. Irish Acad.* vol. xxv.
[9] *Adversaria Anat.* iii. ; *Animadversio*, xlv. p. 94.

neither of them gives any definite statement regarding the frequency of occurrence of the curvatores coccygis muscles in man. The other authors quoted, with the exception of Henle and Sappey, express themselves as if these muscles were normally present in the human subject. Inasmuch, however, as each of these anatomists, with the exception of Günther, appears to have repeated the observations of one or other of his predecessors, and as none of the recent writers on muscular variations have observed these muscles, it seems to me that so far from being normally present in the human subject, they are of extremely rare occurrence. In the course of my own dissecting-room experience, now extending to the dissection of close upon one thousand subjects, I have never met with them but in the one instance above described. This opinion regarding the rarity of occurrence of these muscles is farther corroborated by the fact above stated, that in the classical work of Henle the existence of these muscles in the human subject is entirely ignored.

The normal absence of these muscles in the human subject, as well as in the highest apes, together with their all but constant appearance in the lower mammals, is a fact of much interest in these days of evolutional hypotheses.

VALVULAR HÆMATOMA. By George A. Gibson, M.B., D.Sc. Edin. (Plate XXV.)

On removing the right auricle of a sheep's heart lately, I observed a small tumour upon the auricular surface of the inferior tricuspid valve, very near its attachment to the muscular wall of the heart. The tumour was oval in outline, and measured 4 lines in length and 2½ in breadth; it was of a deep purple colour, with a smooth and glistening surface, the endocardium everywhere being perfectly healthy.

None of the works on pathological anatomy supply any key to the nature of the tumour. It bore no resemblance to the so-called valvular aneurism, nor could it be compared to infiltration by inflammatory products, for in the one case there would have been the fringed aperture, and in the other the villous character of the covering endocardium. It appeared to me that it was most probably an extravasation of blood within the valve substance, arising from one of the minute arterial twigs which supply the valve, a condition which must be extremely rare, as I can find no reference to it.

After hardening, the valve and tumour were cut in the freezing microtome, and the sections, which were stained with picro-carmine, were mounted in Farrant's solution. These sections (shown on Plate XXV.) prove that the tumour has had its origin in an extravasation of blood.

With a low power the endothelial covering, *a a'*, fig. 1, deeply stained with the colouring solution, is seen to be perfectly intact over the whole valve. The fibrous tissue composing the valve, *b*, faintly stained by the picro-carmine solution, is invaded by a yellow mass of finely granular material, which has evidently assumed its position gradually, as the surrounding fibrous tissue has been separated without tearing. This mass of granular matter is of a straw-colour towards its periphery, *c*, and becomes yellowish-brown in the central portion, *c'*; it is everywhere unstained, and by shrinking has produced spaces both within its own substance, *d'*, and around it, *d*. Around almost the entire circumference of the granular matter are

bands and processes, consisting of delicate fibrils, stained to the same depth as the proper tissue of the valve. They spring from the valve tissue and penetrate even to the central portion of the tumour. In fig. 1 they are seen at *e*, springing from the substance of the valve, at *e′* surrounding the granular mass, and at *e″* ramifying in its internal part.

With a higher power the tumour is seen to be composed internally of broken-down blood corpuscles, and, towards the periphery, of the same elements in the form of a finely granular debris. Around the circumference it is infiltrated with cells and traversed by bundles of delicate fibrillæ in the neighbourhood of the larger bands and processes observed with the low power. The part shown in fig. 2 is from the junction of the tumour and the valve tissue. The connective tissue of the valve, *b*, containing fusiform cells arranged longitudinally, is bordered by a finely fibrillated band, *e*, from which processes run out to ramify along with others, *e′* and *e″*. These bundles and processes divide the peripheral part of the tumour into apparent compartments differing in constitution.

At *c* the tumour tissue has become fibrillated and infiltrated with cells arranged in lines parallel to the bounding bundles of fibrils. The irregularly quadrangular space, *c′*, immediately below, also contains many cells and fibrils arranged in the same manner as above, but in less proportion to the granular matter, and in both of these spaces the formed elements have been stained by the colouring matter so as to have a pink tinge running through the yellow tint. The space *c″* is almost entirely granular, only a few cells being present, and the space *c‴* is absolutely free from the invasion of any cells or fibrillæ.

At *f* an artery of small size is seen in transverse section. Whether it may have been the source of the extravasation cannot be determined from any of the sections preserved.

In this tumour we have a beautiful example of the changes which occur in a blood-clot under favourable conditions. Shut off from all extraneous influence, the process of change has been permitted to advance without any interruption, so that we can trace the different stages.

The transformation of the effused blood corpuscles into amorphous material, accompanied by coincident decolorisation,

proceeds from circumference towards centre. Along with this change there is permeation of the peripheral zone by connective-tissue cells and invasion by fascicules of growing white fibrous tissue, attended by absorption of the granular debris. Nearest the proper tissue of the valve the tumour is almost entirely built up of connective tissue which has replaced the absorbed amorphous elements. A somewhat longer term of existence would have allowed the fascicules to pervade the central area, as yet not quite within reach of their influence, and in a short time the tumour would have terminated in a fibrous neoplasm contracted to a much smaller size.

I place this observation on record as being of interest on account of its bearings upon cardiac pathology, and wish in conclusion to offer my thanks to my friend and former teacher, Dr D. J. Hamilton, for his kindness in permitting me to make use of his laboratory.

Explanation of Plate XXV.

Fig. 1 ($\times$ 65). *a a′*, endothelial layer, and *b*, fibrous tissue of the valve; *c c′*, amorphous debris; *d d′*, spaces left by contraction; *e e′ e″*, fibrous fascicules.

Fig. 2 ($\times$ 300). *b*, proper valve tissue; *c*, amorphous material transformed into connective tissue; *c′*, the same undergoing the process; *c″*, the same just at the commencement of the change; *c‴*, the same as yet unchanged; *d d′*, spaces left by contraction; *e e′ e″*, fibrillæ ramifying in the granular matter; *f*, an artery in section.

A CONTRIBUTION TO THE PATHOLOGY OF *MACROGLOSSIA* AND *HYGROMA*. By ROBERT MAGUIRE, *Student of Medicine in the Owens College, Manchester*. (PLATE XXVI.)

IN a very able paper on Lymphangeiomata (*Langenbeck's Archiv.* vol. xx. p. 641), Wegner divides these tumours into three classes—simple, cavernous, and cystic. The simple lymphangeioma consists chiefly of dilated lymph spaces and lymphatic vessels, freely anastomosing with one another, the cavernous lymphangeioma being composed of a trabecular network of fibrous tissue and large macroscopic spaces filled with lymph, and again freely communicating with each other; while in the cystic class the enlargement of the lymph spaces and vessels has reached such a degree that their communication with the lymphatics can in most cases be no longer detected, and to the naked eye the tumour has the appearance of a mass of cysts filled with lymph alone or with lymph and blood, and separated from each other merely by a network of fibrous tissue.

It is apparent that although this classification is very convenient yet the three forms described must very easily pass into one another, and it is quite conceivable that one tumour may exhibit in different parts the appearances of all three varieties.

A typical example of the simple lymphangeioma is found in macroglossia, especially in its congenital form. The pathology of this interesting but extremely rare disease was first correctly observed and described by Virchow (*Krank. Geschwülste*, Bd. iii. p. 487), but subsequent observers differed in their views, some finding in cases of macroglossia, chiefly hypertrophy of the muscular elements; others, hypertrophy of the fibrous tissue; and others, again, increase of both elements. These observations are now of old date, and belong to a period when the histology of the lymphatics was not so completely known as at present, and, no doubt, some of the appearances, such as proliferation of the muscle nuclei, would now admit of a different explanation

than at that time. All the recent anatomical investigations of congenital macroglossia (see cases of Arnstein, Arnott, Winiwarter, and Wegner) agree in considering the changes in this disease to consist of an infiltration of the interstitial tissue by a young cell-growth and the presence of numerous spaces filled with lymph and lined by an endothelium, being evidently, therefore, dilated lymphatics. Doubt is thrown on the older observations by the fact that Wegner re-examined four cases previously described by Maas, and considered by him to be hypertrophy of the fibrous and muscular tissue with increase of the blood-vessels, and found that three out of the four cases were true lymphangeiomata, while the fourth, showing certainly increase of the muscular tissue, was altogether different from ordinary macroglossia, and seemed to consist of congenital unilateral hypertrophy of the tongue, face, and trunk.

While, thus, nearly all cases of macroglossia would belong to Wegner's class of simple lymphangeiomata, only two cases are recorded (Winiwarter and Valenta, see bibliographical list)[1] in which the macroglossia was associated with lymphangeioma of other organs, and I can find no instance where, as in the case which is the subject of this notice, the tongue itself showed to the naked eye a number of small cysts, so that it was easily observed, that, in addition to the simple form, we had here in parts the characters of the cystic variety. The case was further complicated by the presence of cystic lymphangeiomata on each side of the neck, one being of very rapid growth.

The extreme rarity of such a case, and its important bearing on the pathology of the disease, must be my excuse for putting the case on record.

Gertrude H., aged two years, was admitted into the Manchester Royal Infirmary on November 27, 1879, under the care of Mr Walter Whitehead, to whose kindness I am indebted for permission to publish the case.

From birth it had been noticed that the child's tongue had been very large, but it had increased in size for a few months

[1] A case is also reported by Krönlein from Langenbeck's Clinique (*Lang. Archiv.* vol. xxi., Supplement, p. 97), in which macroglossia was complicated by a swelling below the jaw, but as the patient recovered after removal of the tongue, there was no opportunity of proving that the tumour was a true hygroma.

before admission, and, during the same time, the tumour of the neck, described below, had made its appearance.

On admission, the tongue was observed to fill the mouth and to protrude from the lips, the protruded part being hard, dry, and covered with enlarged papillæ. On the surface of the tongue were seen a number of *small clear cysts*, those on the dorsum being about the size of a pin's head, those on the under surface much larger. The lips were not thickened. There was an enlargement under the chin and on the left side of the neck as far as the angle of the jaw, tense, presenting an obscure sense of fluctuation, the skin over it not discoloured, but the superficial veins being very prominent. The child was able to eat and swallow perfectly well. The temperature showed sudden rises, chiefly in the evening, once rising to 105°, and rarely below 102°.

On February 12th, the anterior third of the tongue was removed with scissors. A few days afterwards the tongue increased somewhat in size but afterwards declined.

On March 8th, tracheotomy was performed, and on the 10th a little bronchitis is reported; on March 15th, the tongue was removed by Mr Whitehead's method, the operation being attended by much hæmorrhage. Three days afterwards the tumour in the neck was much enlarged, and swelling, of rapid growth, now appeared on the right side of the neck.

On March 20th the child died from asthenia, and a *post-mortem* examination was made about eight hours afterwards.

A curious point in the clinical history is the fact of the sudden enlargement of the hygroma after the removal of the macroglossia, a similar phenomenon being mentioned by Winiwarter in his paper.

Of the changes found *post-mortem* there is only to be noticed the presence of the cystic lymphangeioma or hygroma on each side of the neck, and some masses of lobular pneumonia in both lungs. The lymphatic glands of the neck were found enlarged, but no distinct connection between them and the hygroma could be discovered. The thoracic duct was carefully dissected out and seemed pervious along its whole length. It was impossible, however, to inject either the hygroma or the glands of the neck from the thoracic duct.

The part of the tongue which had been amputated, the hygroma, and the portion of the stump of the tongue which had undergone cicatrisation after the first operation were afterwards carefully examined in the pathological laboratory of Owens College, and the following is a description of the appearances found:—

Tongue.—The tongue after removal was found to contain a number of cysts, which, towards the under portion, were some of about the size of a cherry-stone. These cysts were filled with a clear fluid, which, on microscopic examination, was found to contain a few red and white blood-corpuscles. Sections of the tongue were made at once, and stained with nitrate of silver and carmine, while other portions were hardened with bichromate of ammonium and afterwards stained with logwood solution.

On microscopic examination of the sections, large irregular spaces were seen, which were evidently dilated lymphatics (fig. 1). Occasionally traces of a flat endothelium lining the spaces were observed (see fig. 4), but for the most part this was not seen. The greater number of the spaces were empty, but many were filled with coagulated fibrin, and a few white blood-corpuscles, while in some few nothing but a mass of hæmorrhage was found. Surrounding the spaces a large quantity of new growth was seen consisting of young cells and embryonic fibrous tissue, embedded in which numerous blood-vessels appeared, their walls much thickened and infiltrated with a new cell growth. In a few places masses of extravasated blood were observed.

The muscular bundles seemed to be embedded in the cellular new growth described, this having also penetrated in many parts into the spaces between the individual fibres. The muscular fibres were apparently not hypertrophied, but the muscle nuclei were markedly proliferated (see fig. 3). Careful comparison was made between the section and other sections from the normal tongue of a child about the same age as the patient from whom the specimen was obtained, in order to discover, if possible, any changes in the muscle tissue, but no other points than those reported were observed.

The epithelium of the tongue was found to be a little increased

in quantity, and the papillæ were much enlarged, so as in some spots almost to form papillomata. The lower portions of the papillæ were occupied by a very large infiltration of young cells, without, however, any definite arrangement, as reported in some of the papers mentioned below.

Hygroma.—Below the inferior maxillæ on each side was a large mass, occupying the floor of the mouth, reaching backwards to the larynx, and downwards to about midway between the chin and the sternum. The tumour on the left side also extended some distance on to the ramus of the jaw. The tumour felt solid to the touch, and on section thin muscular tissue was found covering it, the main mass consisting of fibrous, and a small quantity of adipose tissue, in the midst of which were large dilated blood-vessels and cysts, resembling those described in the tongue, but of larger size. An attempt was made to stain the lining membrane of these cysts with nitrate of silver, but was unsuccessful.

In sections prepared as in the case of the tongue, large spaces were again seen, most of them filled with granular matter and white blood-corpuscles, some completely filled with hæmorrhage, while in others the centre of the space was occupied by a small coagulum of fibrin and white blood-corpuscles, and surrounding this a mass of hæmorrhage completely filled the space (fig. 2). In many of the spaces a flat, nucleated endothelium was well marked. Surrounding some of the spaces a quantity of coagulated fibrin was found, while round all was a large quantity of new fibro-cellular growth, with blood-vessels and hæmorrhages, as described above in the tongue. In the hygroma, however, several masses of old blood pigment were seen, and in a few spots fully formed fibrous tissue was found, probably being the remains of the former structure of the part, and much infiltrated with young cells. The adipose tissue showed signs of irritation, its nuclei being proliferated, and infiltration of cells being again observed.

Cicatrix of the Tongue.—In the stump of the tongue left after the first operation, ordinary cicatricial tissue was seen, in which were spaces lined with endothelium, some filled with red blood-corpuscles and evidently blood-vessels, but others also more irregular in form, and filled with coagulated fibrin and a few

white corpuscles, these presumably being lymphatic spaces. Many small vessels were found, lined again by endothelium, many of which, no doubt, were blood-capillaries, but a few of them could be detected entering the spaces containing fibrin, and described above as lymphatic spaces, and hence we must consider these vessels as lymphatic capillaries.

Remarks.—To summarise the chief changes described here, we find as the most striking those affecting the lymphatics. These are dilated often to such an extent as to form large spaces readily seen with the naked eye; their contents consist merely of coagulated fibrin, but occasionally we find distinct hæmorrhage into them. Whether this hæmorrhage is due to rupture of the walls or to communications between the small terminal venules and these spaces it is impossible to say. This form of hæmorrhage seems to be of frequent occurrence in cases of lymphangeioma, and has been specially dwelt upon by Wegner and Arnstein. The cysts, so numerous both in the tongue and in the hygroma, must be looked upon as arising from excessive dilatation of the lymph spaces, and the occlusion of their communications with the remainder of the lymphatic system, as shown by their lining membrane and the nature of their contents. It will be seen that in no part of the specimen was there anything pointing to a new formation of lymph spaces or lymphatics, and I am inclined to look upon the whole appearance both of the tongue and of the hygroma as due to some congenital impediment to the flow of lymph from these parts into the thoracic duct. (It has already been stated that it was impossible to inject the hygroma from the thoracic duct, but much stress must not be laid on this, for at the time the attempt was made the parts had been in alcohol for some little time, and the structures of the neck had been cut into for the purpose of examination.)

On referring to the literature of the subject, I find that other observers in many of their cases came to a similar conclusion and considered the macroglossia to be due to a gradual dilatation of the lymph channels. In some few cases there has been observed an active proliferation of the endothelium lining the lymphatics (Wegner, *loc. cit.* p. 686), forming solid cell masses, these being supposed to produce eventually new lymphatics. Other observers (Virchow, Billroth, and Winiwarter) describe a

third mode of formation of these tumours, assuming the formation of a granulation tissue from the pre-existing areolar tissue, which granulation tissue afterwards becomes changed into lymphatics.

Without disputing either of these latter modes of formation, I can only say that in the case described above no such proliferation of the endothelium or of the areolar tissue was found, except, perhaps, underneath the papillary epithelium.

There were, however, certain changes to be seen both in the areolar tissue and in the muscular substance. The areolar tissue round the lymphatics showed cellular infiltration, which, however, I take to be due simply to irritation set up by the stagnating lymph in the neighbouring parts. This view is also borne out by the evident state of irritation of the adipose tissue. The muscles also show proliferation of their nuclei. This, no doubt, was seen by older observers, and believed to point to commencing muscular hypertrophy; nowadays, however, we should look upon such proliferation as due to commencing atrophic changes, and as such I am inclined to view this appearance. In connection with this part of the subject there is an important paper by Litten in *Virch. Archiv.* 1880.

The infiltration of the lowest stratum of the papillæ of the tongue with round cells, which is noticed above, has been described in several cases of macroglossia, and some observers have even looked upon the cell-infiltration as a cell-proliferation, and have described a gradual change of these round cells into polygonal and epithelioid cells, with an arrangement of them into lines and tracts, and believe that eventually they form new lymph channels. I was not able, however, to detect a similar appearance in my preparations. I am inclined, therefore, to look upon all the changes seen in the papillary layer of mucous membrane, in the muscles, and in the areolar tissue, either to irritative or atrophic changes, and to look upon an impediment to the lymph flow as the chief cause for the formation of the cystic lymphangeioma, which showed itself both as the macroglossia and as the hygroma.

As to the appearances of the cicatrix nothing much can be said, except, as had already been noticed by Winiwarter in similar circumstances, there were indications that in time a

structure similar to the remainder of the tongue would develop.

Literature.—The literature of lymphangeioma is well given by Gjorgjewic (*Langen. Archiv.* vol. xii. p. 641), and by Wegner (*loc. cit.*). Two similar cases to that described above, but with the macroglossia only as a simple lymphangeioma, are reported by Valenta (*Œsterreich. Jahrbuch für Pædiatrik,* vol. ii. p. 35), and Winiwarter (*Langen. Archiv.* vol. xvi. p. 655).

Other cases of lymphangeioma will be found in *Langenbeck's Archiv.* by Waldeyer and Fischer, vol. xii. p. 845; Maas, vol. xiii. p. 420 (examined by Wegner); Dollinger, vol. xxii. p. 701; Schwerin, vol. xxiii. p. 430; Krönlein, vol. xxi. Supplement, p. 97. In Billroth and Pitha's *Handbuch,* by Billroth, Bd. ii. Abtheilung 1, p. 268. In Virchow's *Krank. Geschwülste,* Bd. iii. p. 487. In *Virchow's Archiv.* by Virchow, vol. vii. p. 126; Weichselbaum, vol. lxiv. p. 145; Arnstein, vol. liv. p. 319; Langhans, vol. lxxv. p. 293; Steudener, vol. lix. p. 413; Reichel, vol. xlvi. p. 797.

The English literature is not rich on this subject, but cases may be found in the *Pathological Transactions* by Arnott, 1872; Jones, 1875; Tilbury Fox, 1879.

I must express my thanks to Dr Dreschfeld for the assistance which he has rendered me in many points of the subject, and I am also indebted to my fellow-student, Mr Sidney Young, of the Chemical Laboratory, for the drawings which accompany this paper.

Explanation of Plate XXVI.

Fig. 1 is a section of the tongue under a low power, showing several lymphatic spaces, surrounded by small cell-growth.

Fig. 2 represents one of the spaces of the hygroma, surrounded again by new growth. In its centre is (*A*), a coagulum of fibrin and white corpuscles, surrounded by (*B*) red corpuscles, the remains of a hæmorrhage into the space.

Fig. 3 shows the proliferation of the muscle nuclei.

Fig. 4 represents the remains of an endothelium found in one of the spaces of the tongue. This appearance is evidently not due to proliferation of the endothelium, for the cells are much larger than would have been expected in such a condition, they have each only one nucleus, and they form only one layer.

ON THE CHANGES IN THE SPINAL CORD AFTER AMPUTATION OF LIMBS. By J. DRESCHFELD, M.D., M.R.C.P., *Lecturer on Pathology, Owens College, Manchester.* (PLATE XXVI.)

AMONGST the pathological changes of the spinal cord there are few which possess a wider interest than the so-called "secondary degenerations," for they interest not only the pathologist, but also the anatomist and physiologist, inasmuch as they give us precise information of the course of certain tracts of nerve fibres, and of the functions of certain parts of the nervous system. The several ganglionic centres of the cerebro-spinal axis being connected together, and also with the periphery, by conducting nerve fibres, it is now a well established fact that lesions of one part can be traced along the conducting fibres to other parts functionally connected with the diseased or deranged part. In the spinal cord two forms of secondary degeneration are thus found of definite character and well limited extent, namely, the descending and ascending.

The descending degeneration, as is well known, occupies the anterior and lateral pyramidal tract (with certain exceptions which need not be considered here), and is dependent on lesions either of the cortical motor centre or some part of the motor tract, while the ascending degeneration, which follows pressure, injury, or disease of the spinal cord, occupies the region of Goll's fibres, and of the "direct cerebellar" tract (Flechsig's), and can be traced upwards along the whole length of the spinal cord from the seat of lesion. (Lesions of the cauda equina show the same ascending changes in the cord higher up, while in the lumbar region the whole of the posterior columns (Goll's and Burdach's tract) is secondarily affected, as I had an opportunity of observing in a recent case, and as was seen in some few other cases published).

Besides these two there is another, more partial, secondary degeneration of the spinal cord, ascending in its nature and dependent on lesion of a large peripheric nerve trunk. Experi-

mentally this form of degeneration has been studied by Vulpian (*Arch. de Physiol.* 1869, p. 683) and Hayem (*Arch. de Physiol.* 1873, p. 504, and again in *Gaz. Medic. de Paris*, 1875), by tearing out the sciatic nerve in animals, or by crushing that nerve, or by the application of irritating substances to the trunk of the nerve. In man a similar degeneration in the spinal cord has been found following various pathological conditions, all having this in common, that the peripheric nerves, or the parts supplied by them, are primarily affected. Leaving out of consideration a number of diseases, of which it is doubtful whether the lesion is primary in the spinal cord and secondary in the peripheric nerves and muscles, &c., or in which the changes in the spinal cord are of indefinite character, and not constant in their occurrence, there is one class of cases in which the primary lesion is undoubtedly peripheric, and where secondary changes in the spinal cord are almost invariably found, to which I wish now to refer, namely, those cases in which at some antecedent date, usually several years before death, amputation of a limb had been performed.

As the cases on record are not very numerous, and as the changes observed by the different observers are not all alike, I will briefly review the best observed of these cases previous to giving my own observations:—

Amongst the older observations there is one of Bèrard, who in 1829 showed before the Anatomical Society of Paris the spinal cord of a soldier who had his arm amputated at the Battle of Waterloo, and where the anterior roots of the nerves going to the arm were found atrophic and reduced in size. Cruveilhier and Türck, on the other hand, got negative results in similar cases. More precise and definite changes were found by Dickinson (*Journal of Anat.* vol. iii. p. 88). In one case (amputation of left thigh fifty-three years before death) the sciatic nerve of the stump showed granular degeneration, and the lumbar enlargement atrophy of the posterior column on left side was found. Lockhart Clarke (*Med. Chirurg. Trans.* vol. li. p. 249) examined the sections from the same cord, and found distinct atrophy of the motor ganglia (the postero-lateral group—to judge from the drawings accompanying the paper) in the lumbar enlargement on the left side.

In the second case (amputation of left arm twenty-three years before death) the anterior and posterior roots were found atrophic, and posterior columns affected, the affection (chiefly sclerosis) could be traced up to the decussation of the cord. The posterior grey matter on the same side was slightly affected; but the motor ganglia in the anterior horns seem not to have been affected.

The third and last case (amputation of right forearm twenty-three years before death) showed atrophy of the right posterior column, affecting also the posterior grey matter on that side, and implicating also the right anterior horn.

Vulpian (*Arch. de Phys.* 1868, p. 443) found in one case (amputation of right leg forty-seven years before death) diminution in size of lumbar region on right side, affecting grey and white matter anteriorly; and in another case (amputation of left leg twenty years before death), changes along the whole cord on left side, consisting chiefly in atrophy of anterior white and grey matter, atrophy of the motor ganglia cells, and granular degeneration in anterior grey matter.

The differences between the results obtained by Dickinson and Vulpian concern, as will be seen, chiefly the posterior column and grey matter, which Vulpian did not find affected in his cases. This led to some further observations by Vulpian (*Arch. de Phys.* 1869, pp. 678, 690) on some other cases. Of these, two showed marked changes in posterior white and grey matter, and no perceptible changes in the anterior horns or anterior white matter, while the third case (amputation of left forearm one and a half year before death) showed again no changes in posterior part, while the anterior white and grey matter were found affected along a considerable tract.

Friedreich (*Progress. Muskelatraph.* p. 140) examined one case (amputation of left forearm twelve years before death), and found the spinal cord perfectly normal. Dickson (*Path. Trans.* 1873, vol. xxiv. p. 2) reports on the examination of a case where amputation of right leg had been performed fifteen years before death. He found changes chiefly in anterior grey horn of lumbar region, where many of the ganglia cells were found atrophied, and their number diminished. From his drawings it is again evident that the postero-lateral group of cells is the one principally affected.

Genzmer (*Virch. Arch.* vol. lxvi. pl. ix.) found similar changes,—atrophy of the large ganglia cells in anterior horns in lumbar enlargement; in one case (amputation of right thigh thirty years before death).

Lastly, Leyden (*Klinik. der Rückenm. Krankheiten,* vol. ii. p. 316) gives three cases (one amputation of arm, one of leg, and one of thigh), in all of which atrophy of the corresponding half of the spinal cord was found. This was best marked in the case of amputation of thigh; here the anterior and posterior roots were found thinner, the corresponding half of the lumbar region of cord was found distinctly wasted, the affection chiefly resting with the external part of anterior grey matter, "where ganglia cells must have disappeared."

To the foregoing list I now beg to add the following observation made on the spinal cord of a man who had his left thigh amputated fifteen years before death, and who died a few days after the ligature of the left common iliac artery for an arterio-venous aneurism. The *post-mortem* was made six hours after death. Beyond a large "amputation neuroma" at its peripheral end, the left sciatic was perfectly healthy, the anterior and posterior roots on left side showed no changes to the naked eye, and when afterwards microscopically examined were found to be perfectly healthy. The spinal cord was carefully removed and cut in small sections, which to the naked eye showed neither unilateral atrophy nor changes in colour or consistency. The two halves of the brain were likewise symmetrical, and the cortical motor area of the same dimensions on both sides. The spinal cord was at once placed in one per cent. solution of ammonium chromate, was kept at a low temperature, and was examined when sufficiently hardened in the usual way, when the following interesting appearances were noticed:—

Sections of the hardened and stained spinal cord in the lowest lumbar region (see fig. 1) showed to the naked eye a slight diminution of the left anterior horn, while the other parts seemed of the same size on the two sides. Microscopically the right half showed nothing but normal relations; in the anterior horns the several groups of cells were distinctly mapped out; the internal group (or Erb's anterior group, marked *a* in fig. 1) was not so well expressed, and the tractus intermedio-lateralis con-

sisted of two groups of cells; but the separate cells were well defined, and, especially those occupying the tractus intermedio-lateralis (*b* fig. 1) were at once recognised by their large size. The appearance of the cells in the left anterior horns contrasted most markedly with that of the corresponding groups on the right side. In the several cell groups there were only seen three to four small atrophied cells, not pigmented, without any out-runners, and with their nuclei scarcely visible. Beyond these atrophied nerve cells the grey matter in the anterior horns showed no other changes, with the exception of a small spot at the external lateral border, and corresponding to the intermedio-lateral group of cells, where the granular material surrounding the still remaining but atrophied ganglia cells had taken a deeper staining than any other part of the cord, and was found to consist of masses of granules and fine fibrillæ.

Except these changes concerning the different groups of ganglia cells in the anterior horn, no changes whatever could be found either in the anterior white or posterior grey or white matter.

Sections of the spinal cord a little higher up, but yet low down in the lumbar enlargement, showed a somewhat different appearance (as seen in fig. 2). While the right half was perfectly normal, in the left half the intermedio-lateral group of cells in the anterior horns was found atrophied, diminished in number, and surrounded by masses of granules and fabrillæ, which took the carmine staining better than any other part of the cord. The other groups of cells, especially the antero-lateral and median, were well marked, though the several groups contained a smaller number of cells than the corresponding groups on the second part. Beyond a slight diminution of the posterior horn on the left side, no other pathological changes could be noted.

On examining sections still higher up in the lumbar region (fig. 3), the several cell groups in their anterior horns received their full complement of cells, except the intermedio-lateral tract, which remained in its atrophic condition. The other parts of the spinal cord were again devoid of any pathological changes. (The drawings kindly made for me by Dr Young, Pathologist to the Infirmary, show these changes well.) Beyond the lumbar

enlargement, both sides were found healthy along the whole length of the spinal cord.

If we now analyse the results of the several observations, we have to consider—

1. Which parts of the spinal cord are found affected.
2. What is the nature of the lesion found; and
3. What are the physiological bearings?

As to the first of these questions, we find certain agreements and certain discrepancies in the observations recorded. Changes in the trunks of the large peripheric nerves are recorded in only one case of Dickinson's. Vulpian and others, and amongst them myself, have not detected any changes in the peripheric nerves. The nerve-roots, again, were found altered by Dickinson and by Leyden, and seem in most of the other observations to have been unaltered. As regards the spinal cord itself, the white matter has been found in most observations (with the exception of Dickinson's, and a few of Vulpian's cases) intact; the posterior grey matter has been found altered in many of the recorded cases, but has been found absent in those cases most recently reported (Dickson, Genzmer, myself). On the other hand the changes in the anterior grey matter are of the most constant occurrence, and though missed in some of the older observations, have been found in all the recently recorded cases. These changes affect chiefly the ganglia cells, and though most authors have not sufficiently distinguished between the several cell groups, a glance at the drawings accompanying the description of the several cases will convince anybody that the intermedio-lateral tract of cells is the one constantly attacked.

It will be further observed that the time elapsed between the amputation of the limb and the death of the individual does not in any way account for the want of harmony between the several observations.

As to the second point of our inquiry, there can be little doubt that so far as the changes in the spinal cord itself are concerned, the nature of the lesion is of a purely degenerative character. The changes in the trunks of the nerves possibly result from a chronic inflammatory process leading to degeneration; the lesions of the cord, on the other hand, especially when the intervening peripheric nerve and nerve-roots are found intact,

are essentially of atrophic nature. The changes in the motor ganglia of the anterior horns show this in a marked manner; some have completely disappeared, and those that remain are found small, not pigmented, shorn of their processes, whilst the grey matter, beyond a slight increase of the neuroglia, shows none of the changes seen in inflammatory affections, such, for instance, as in infantile paralysis.

In considering, lastly, the physiological bearings of these changes, and their relation to one another, we derive some aid from the experimental researches of Hayem (*loc. cit.* p. 511), who tore out, in rabbits, the sciatic nerve of one side, and found in the corresponding side of the spinal cord, in the lumbar region, a sclerotic condition of the posterior roots and posterior grey matter, and simple degenerative atrophy of the ganglia cells in the intermedio-lateral tractus. These changes, it will be seen, include the most important ones, and those most constantly found after amputations. Again, in locomotor ataxy, when in the course of the disease there is observed muscular atrophy, there has been observed, *post-mortem*, besides the changes in the posterior columns and posterior grey matter, a distinct atrophy of these large motor cells in the anterior horns.

Now, the changes in infantile paralysis, progressive muscular atrophy, and any atrophic lateral sclerosis, have led many observers to look upon these large motor ganglia as possessing atrophic function; and I think this view will also explain how it is that these ganglia cells are affected in cases of amputation, when they no longer need preside over and regulate the nutrition of a mass of muscles.

About the relation of these ganglia cells to the posterior grey matter, the posterior roots, and the sensory nerves, we have at present no very precise information. While I am inclined, therefore, to look upon the atrophy of these ganglia as supporting the view of their trophic function, I have yet to explain the atrophy of the other ganglia groups in the lowest lumbar region, as seen in our case (fig. 1). Seeing that these atrophic groups were only found in the lowest part of the lumbar region of the cord, it is highly probable that they are connected with the motor nerves going to the different groups of muscles of the foot and leg, and that they have undergone atrophy after the amputation

from disease simply. On looking at the different groups of cells in the spinal cord, seeing how they vary in the different regions, and also in different animals, and how certain of them seem to appear much later than others in the embryo (see a paper by Dr Ross in "Brain," 1880), one cannot help thinking that the several groups of cells supply separate groups of muscles, and the atrophy of these cells on the disappearance or disease of the muscles is thus easily understood.

The whole subject is one of great interest, and will require many and varied observations before more positive conclusions can be arrived at. It is, however, highly desirable that in all future observations on lesions of the grey matter of the spinal cord, the different groups of ganglia cells should be considered separately, and not collectively, as has hitherto been done.

Explanation of Plate XXVII.

Fig. 1. (Section of lowest lumbar region.) *a.* Group of internal cells not well seen. *b.* Group of cells in intermedio-lateral tract. *b′.* Groups of atrophied cells.

Figs. 2 and 3. (Sections of lumbar region higher up.) *b′.* Group of atrophied ganglia cells.

ON THE MORBID ANATOMY OF CERTAIN FORMS OF POST-SCARLATINAL NEPHRITIS, IN RELATION TO THEIR BEARING ON THE HISTOGENY OF GRANULAR KIDNEY.

By BRYAN CHARLES WALLER, M.D., F.R.C.S. Edin., *Lecturer on Pathology in the School of Medicine, Edinburgh.* (PLATE XXVII.)

UNTIL a comparatively recent period, post-scarlatinal nephritis was generally thought to belong exclusively to the parenchymatous variety. It was considered that the kidneys were subjected to abnormal irritation by the scarlatinal poison, and also to vicarious overwork consequent on the deficient action of the skin, and the necessity for the elimination of large quantities of waste products. The brunt of the lesion was supposed to be borne principally by the secreting cells of the uriniferous tubules, which became cloudy, granular, and fatty, and were loosened from their basement membrane and cast off in the urine.

Without doubt, in a considerable percentage of cases, these older views are perfectly correct. The clinical symptoms are those of ordinary acute Bright's disease, the urine is diminished and albuminous, and contains renal epithelium, blood corpuscles, and tube casts in abundant quantity; and the condition runs the ordinary course of acute Bright, frequently terminating in recovery more or less complete, according as the renal inflammation subsides, or passes into the chronic form.

Yet though parenchymatous or intratubular nephritis is a frequent sequela of scarlet fever, it is by no means the only form of nephritis liable to supervene upon this disorder. A variety of other morbid appearances have been chronicled from time to time by different observers, among whom may be mentioned Drs Wilks, Bristowe, Cayley, and Coats, Arnold Beer, Biermer, Wagner, and others. The cases recorded by these authorities differ materially from ordinary parenchymatous inflammation, for in those of Biermer, Coats, Wagner, and Cayley the morbid changes were interstitial, while in those of Beer, Bristowe, and Wilks the glomeruli were the parts specially affected.

Klebs, however, was the first to make prominent mention of a post-scarlatinal nephritis leading to peculiar and remarkable changes in the glomeruli (*Handb. der Path. Anat.* lief iii. pp. 644–647). To this he gave the name of glomerulo-nephritis. He describes the interior of Bowman's capsules as occupied by a number of small angular nuclei imbedded in a finely granular mass (see figs. 1 and 2, and Klebs' engraving, *loc. cit.*). These nuclei he evidently considers as springing from a proliferation of the normal corpuscles of the connective tissue of Axel Key, which binds the capillaries of the Malpighian tufts into compact balls. In normal kidneys these corpuscles are not difficult to demonstrate, especially in specimens of cats' kidney stained with logwood after successful injection with carmine and gelatine. A glomerulus is carefully picked out whole, and placed on a separate slide with a drop of water; a moderately thick cover-glass is then pressed firmly down upon it, and moved slightly from side to side so as to dissociate the capillary loops, or these are carefully separated from one another with fine needles under the dissecting microscope. Either of these processes, if properly conducted, will afford a ready demonstration of the glomerular connective tissue. Its corpuscles stain deeply with logwood, and are therefore easily identified. They are seen to be situated in the substance of the glomerular ball, between its component capillaries. Their anatomical site is consequently different from that of the epithelial cells forming the glomerular investment, from which they further differ in form and size.

In glomerulo-nephritis Klebs describes an enormous increase in the number of these corpuscular bodies, which completely fill Bowman's capsules, obscuring the glomeruli, compressing and emptying the capillaries, and thus seriously interfering with renal circulation and excretion (see figs. 1 and 2). According to Klebs, the corpuscular accumulation inside Bowman's capsules is the only morbid condition noticeable in these cases. Clinically glomerulo-nephritis may be recognised by the occurrence of sudden and complete suppression of urine, followed by acute dropsy and uræmic symptoms. The prognosis appears to be very unfavourable, as, indeed, might be conjectured from the anatomical characters of the morbid changes.

Of this variety of post-scarlatinal nephritis I have seen several typical specimens. So far as regards the condition of the glomeruli, they corresponded closely with the description given by Klebs; but there were besides a number of other interstitial changes, and some intratubular changes of minor import, which I shall presently describe.

In my specimens the cell-accumulation inside Bowman's capsules was of the nature of a granulation tissue rich in small cells. The capsules themselves were thickened, and their substance was infiltrated with round cells, while outside their periphery was a dense interstitial accumulation of cell structures similar to those occupying their interior. Sometimes a whole Malpighian body was entirely hidden by an accumulation of multitudes of these small cells (see fig. 8). The epithelium of one or two tubules in the immediate neighbourhood of each affected Malpighian body was generally fatty, staining deep black with osmic acid; but the fatty changes were strictly limited to the tubules in these situations, the epithelium of the great majority being still normal, both in the cortical and medullary portions of the kidney. A few leucocytes and red blood corpuscles were, however, occasionally visible in the lumen of the convoluted tubules.

Around many of the veins and arterioles of the kidney there were copious accumulations of small round cells, which were evidently of a migratory nature (see figs. 2 and 5). These, after passing through the vascular wall, had collected in large numbers in the perivascular connective tissue immediately outside it, the structure of the kidney preventing the majority of them from wandering further (see also paper by Klein, *Trans. Path. Soc.* 1877, pl. xxxii. figs. 2, 3, and 4). This migration of leucocytes points to an interstitial nephritis, affecting not only the connective tissue between the loops of the glomeruli and around Bowman's capsules, but also that of the general kidney stroma, though in a somewhat minor degree. In this respect my specimens differed from those described by Klebs, in which there were no evidences of general interstitial nephritis, and resembled those of Klein (*op. jam. cit.*), in many of which similar interstitial changes were observed.

The cellular accumulations inside Bowman's capsules, between

the individual capillary loops and on the surface of the glomeruli were very general and exceedingly abundant. The effect of the pressure of so large a number of cellular bodies inside the inelastic and but slightly distensible capsules must necessarily be to render the arterioles of the glomeruli well-nigh impervious, and thus to interpose a serious obstacle in the way of the passage of the blood stream and the excretion of urine. Indeed, the gravity of the clinical symptoms is fully explained by the histological characters of the affected kidneys. Dr Klein (*Trans. Path. Soc.*, 1877, pp. 435, 436) is disposed to doubt the accumulation of cellular bodies inside Bowman's capsules in sufficient numbers to interfere with the circulation. But, as we shall presently indicate, and, indeed, as he himself admits, his cases were in all probability not true, or at least not typical examples of glomerulo-nephritis. Dr Klein considers the nuclei as being of an epithelial nature. In all of my specimens, save one to which I shall presently allude, this hypothesis appears to be negatived by the fact that the intercapillary situation of many of the nuclear bodies was proved by repeated experimental crushings and teasings out of the glomeruli. The corpuscular bodies were found *between* as well as upon the surface of the capillary loops, a circumstance which, in my opinion as in that of Klebs, must be allowed due weight in determining their nature.

In my cases there could, I think, be no reasonable doubt that the glomerular circulation must have been seriously obstructed by the large nuclear aggregations inside Bowman's capsules. Were further corroboration of this conclusion required, I should be disposed to recognise it in the fibrous state of some of the glomeruli. In two of my specimens a number of glomeruli presented appearances similar to those figured by Dr Klein in plate xxxiii. fig. 7, *Trans. Path. Soc.* 1877. The impervious capillary loops were transformed into a fibrous texture, more or less completely united with the thickened Bowman's capsules. Their lumen was evidently entirely abolished (see figs. 3, 4, 6, and 7). The nuclei on the surface and in the substance of these fibrous glomeruli were much diminished in number, as represented in the above drawings. Their attraction for vegetable colouring matters was also materially diminished. They were stained much less deeply by

logwood than those upon the surface of other glomeruli in the same section, whose capillaries, though compressed and emptied by the pressure of the cell growth, were still apparently capable of renewed distention in event of the removal of the compressing mass. It appears reasonable to suppose that the fibrous change is due partially, and indeed mainly, to abolition of function by compression, but partly also, perhaps, to direct fibrous metamorphosis of the compressing cells, which, as already stated, appear to be of the nature of a granulation tissue.

I am disposed to consider the cell-accumulations inside Bowman's capsules as originating from two sources. Firstly, many of them are probably derived from direct proliferation of the intercapillary connective-tissue corpuscles of the glomeruli, which they resemble in size, general outline, and behaviour with colouring reagents. Indeed, in the earlier specimens of glomerulo-nephritis, where the intracapsular cell accumulations are seen in their initial stages, the appearances are simply those of moderate increase in the number of these bodies (see fig. 1). Their anatomical situation, as previously stated, is between and not on the surface of the glomerular loops,—in the substance of the Malpighian tufts, and not in the interspace between the glomeruli and their investing capsules. But as the morbid process proceeds, this interspace is usually entirely filled with cellular bodies, which are now seen, not only between the capillary loops, but likewise on their free surfaces, occupying the space between the periphery of the glomerular balls and the inner circumference of their investing capsules. So far as their anatomical position is concerned, the cells thus situated might, of course, be derived, as Klein supposes, from an increase in the epithelial elements investing either the inner surface of Bowman's capsules, or the circumference of the glomeruli. But, on the other hand, they differ from epithelial cells in form, size, contour, and attraction for colouring matters; while they are identical in appearance with the intercapillary corpuscles, and are therefore presumably of the nature of leucocytes or connective-tissue cells. I am, accordingly, disposed to consider many of them as migratory leucocytes, and to regard the intracapsular cell accumulations as composed partly of proliferated connective-tissue corpuscles, and partly of migrated blood cells,

which have passed through the walls of the glomerular capillaries. This idea receives confirmation if we direct our attention to the abundant cell-accumulations outside Bowman's capsules, and around the arterioles and small veins of the cortical substance (see figs. 1, 2, and 5). The cells in these situations, and especially the latter, are clearly migratory, while they exactly resemble those in the interior of Bowman's capsules. Further, in pencilled preparations, the lumen of the cortical capillaries is seen to be occupied by numerous leucocytes, which are often so closely aggregated as to show that the circulation through them during life must have been either materially retarded or reduced to a condition of complete stasis. This cramming of the vessels with leucocytes, apparently ready to emigrate, affords additional evidence, if such be needed, of the migratory nature of those cells which have accumulated in quantity outside the cortical vessels. If, therefore, this process of emigration be observable in the case of the ordinary vessels of the cortex, why should not the same conditions produce the same effects in the case of the vessels of the Malpighian tufts? Indeed, the mechanical conditions of these tufts, lying as they do in the midst of a free space, are more favourable to the outward passage of leucocytes than those of the ordinary vessels of the cortical substance; for whereas in the latter the escaping leucocytes must encounter the outside pressure of the surrounding tissues, they find free exit in the former, and pass directly into the unoccupied spaces intervening between the glomeruli and their capsular coverings. The corpuscular as well as the fluid constituents of exudations tend to escape and accumulate where there is space for them; and it is accordingly not surprising that they should select the interior of Bowman's capsules as the site of their lodgment. Normally the glomeruli do not entirely fill up the interior of the capsular expansions of the uriniferous tubules, a space being left for the escape of the fluid urinary constituents as fast as they are exuded from the capillary loops. This space, empty save for the escaping urinary fluid, offers a favourable situation for the diapedesis and accumulation of the migratory cells which expel the fluid and occupy its place, at the same time compressing the glomeruli and producing the characteristic clinical symptom of suppression of urine. The migration of leucocytes

from the glomerular capillaries, assisted by the proliferation of the corpuscles of the interglomerular connective tissue, proceeds until the interior of Bowman's capsules is filled as full as it can hold with small-cell structures. The capsules themselves are dense, tough, fibrous, and practically inelastic, while the Malpighian capillaries are compressible; and, accordingly, the increasing cell-accumulation presently abolishes the lumen of the vessels by outside pressure, and renders them impervious to the passage of blood. Hence the excretory functions of the kidney are interfered with, and anuria, uræmia, and acute dropsy begin to develop themselves.

In my cases the coats of the vessels of the general kidney stroma were quite normal. No germination of muscle nuclei in the tunica media, or hyaline degeneration of the intima, as recorded by Dr Klein (*Trans. Path. Soc.* 1877), was observed in any of them. The outer coat also appeared perfectly unchanged (see fig. 5).

Parenchymatous changes were limited to those tubules in the immediate neighbourhood of the Malpighian bodies, and consisted chiefly in fatty degeneration of the tubular epithelium, though cloudy swelling and granular disintegration were also observed in a few instances.

It will be seen that the specimens included in the foregoing description approximate more or less closely to the glomerulo-nephritic kidney of Klebs. In all of them the salient feature was the excessive cell accumulation inside and around Bowman's capsules, an accumulation which was evidently responsible for the peculiar clinical symptoms. But in one kidney from the body of a boy eight years old, who died in the Aberdeen Infirmary after a three months' illness from supposed parenchymatous nephritis, the morbid appearances were found in many respects analogous to those described by Klein in his paper on the morbid anatomy of scarlatina, to which I have previously referred in the course of the present article. During his residence in hospital the patient suffered from albuminuria and a variable amount of renal dropsy. I am not aware whether cells or casts of any kind were present in the urine. The albuminuria was supposed to have been consequent on scarlet fever; but the history previous to admission was doubtful. The autopsy was

made by my friend, Mr Rodger, Pathologist to the Aberdeen Infirmary, to whose kindness I am indebted for the specimen. The liver was enlarged, yellowish, and highly fatty. The kidneys were heavier than normal, enlarged, pale in colour, and somewhat dense in consistence. Their surface was smooth, and the capsule stripped off easily. The other organs of the body presented no remarkable changes.

On microscopical examination with a low power (Hart. oc. 3, × obj. 3), the Malpighian bodies were seen to have absorbed the colouring matters (carmine and logwood) with great avidity. Their capsules were thickened, and the intertubular septa in their neighbourhood were increased in width.

Examination with a high power (Hart. oc. 3, × obj. 7), showed general fibrous thickening of Bowman's capsules. The interstitial tissue was increased, especially around the Malpighian bodies, and included tubules more or less empty, compressed, and atrophied. The Malpighian bodies themselves had undergone extensive fibrous alterations. Most of them were reduced in size, the vessels of the glomeruli being impervious, fibrous-looking, and wholly or partially united with their thickened capsules into a solid fibrous mass (see fig. 3; see also Klein, *Trans. Path. Soc.* 1877, pl. xxxiii. fig. 7). Where this blending was incomplete, the vascular loops were shrunken and fibrous, occupying considerably less of the intracapsular space than those of normal glomeruli. The interval between the shrunken glomeruli and their capsules was occupied by a few nuclear bodies, but the number of nuclei inside Bowman's capsules was not by any means excessive (see fig. 7). Indeed, in proportion as the fibrous changes in the glomeruli become more complete, the number of cellular bodies inside their capsules appears constantly to diminish,—a phenomenon noticeable alike in the kidney now under discussion, and also in the others previously described, and, as before stated, probably partly due to direct fibrous transformation of the cellular accumulations (see also figs. 4 and 6).

Individual glomeruli here and there were seen in various stages of colloid or hyaline transformation. Others, together with their capsules, were completely converted into fibrous masses, interspersed with a few round cells, and only distinguishable from

patches of increased interstitial tissue by the preservation of an obscure concentric arrangement. These completely metamorphosed Malpighian bodies were only slightly tinged by colouring matters. Few glomeruli were even approximately normal; and the prolongation of life for three months under such conditions is, therefore, the more noteworthy, as proving what serious structural alterations may sometimes occur in the kidneys without inducing an immediately fatal result. The youth of the patient, and the skilled treatment to which he was subjected, probably operated materially in retarding the eventual untoward issue.

The increased intertubular stroma was principally of a finely fibrous character, though in some situations there was a good deal of small-cell infiltration still remaining around the Malpighian bodies. Indeed, the whole aspect of the changes, both inside Bowman's capsules and in the general interstitial tissue, seemed to point to the fibrous transformation of a previous small-cell formation. This consideration would lead us to regard the case as a later stage of the glomerulo-nephritis of Klebs. In all my other specimens the greatest cellular increase was found inside and around Bowman's capsules; and in this kidney the fibrous increase was greatest also in these situations, and still contained a variable number of unaltered round cells, which had not undergone the fibrillar transformation.

Many of the uriniferous tubules, more especially the convoluted tubes communicating with the Malpighian bodies, were the seat of intratubular changes, which were evidently mere secondary consequences of the primary glomerular affection. We have already stated that many of the tubes were compressed and atrophied by the pressure of the fibrous interstitial increase around the glomeruli. Others were more or less completely denuded of their epithelium; in others, again, the epithelium was in a state of fatty or granular disintegration. On the whole, however, when compared with the changes in the Malpighian bodies, these intratubular alterations were comparatively insignificant.

If this description be compared with that in Dr Klein's paper (*Trans. Path. Soc.* 1877), the many points of close resemblance will be sufficiently obvious. In fact, I have little doubt of the substantial identity of this case with those comprised in Dr

Klein's series; the only point of material difference being in the condition of the coats of the small veins, arterioles, and capillaries of the stroma, which in my specimen were perfectly normal. I am, consequently, at present unable to concur with Dr Klein in the importance which he attaches to the vascular alterations in relation to the development of the clinical phenomena. These latter, I am persuaded, are due firstly to compression of the glomeruli by the cell-aggregations inside Bowman's capsules, as supposed by Klebs; and secondly, to the subsequent fibrous degeneration with which these compressed and empty glomeruli are presently affected. Both processes tend, firstly to obstruct, and subsequently to abolish the glomerular circulation, whose special functions are connected with the separation and elimination of the urinary fluids, and probably also of a certain proportion of the solid constituents likewise. Granted the accuracy of Klebs' description of glomerulonephritis, and the feasibility and sufficiency of his explanation of the cause of the symptoms during life can hardly be questioned. My specimens convince me of the correctness of the one, and I am therefore prepared to accept its corollary also.

The information derived from the study of such specimens as the foregoing is not without significance, as bearing on that much debated cognate subject—the histogeny of interstitial or granular kidney. The great diversity of opinion among pathologists with respect to its origin arises principally from the fact that early specimens are very rare, because the disease in its early stages is very seldom fatal. But when the glomeruli are affected, the condition is one of immediate danger to life, and in such kidneys the general interstitial lesions are often seen before sufficient time has elapsed to allow of the masking of the essential process by subsequent changes. They are therefore peculiarly instructive, since they act as it were as the grammar or key to a complicated and difficult language.

In ordinary specimens of granular kidney the indications of the primary source of the interstitial increase are so doubtful as to admit of a number of conflicting interpretations. Thus,

Dr George Johnson considers the intratubular lesions as the primary and essential elements in the process, and regards the increase in the stroma as merely apparent, and produced by a shrinking together of the normal framework consequent on the destruction of the tubes and their epithelium. Sir W. Gull and Dr Sutton are of opinion that granular kidney is but part and parcel of a general morbid change in the system, characterised by the deposition of a hyalin or hyalin-fibroid material in the adventitia of the arterioles, and a hyalin granular change in the walls of the capillaries. MM. Cornil and Ranvier attribute the renal changes to a chronic arteritis. Again, a numerous section of British and Continental pathologists advocate the theory of a true interstitial nephritis, consisting in an infiltration of the kidney stroma with migratory leucocytes, and their subsequent transformation into a more or less completely formed fibrillar tissue.

To these theories yet another has been lately added by Dr Robert Saundby. At a meeting of the Pathological Society of London, held on Tuesday the 16th of March of the present year, this gentleman exhibited a number of specimens tending to prove that the changes in the granular kidney begin by an active proliferation of the tubular epithelium and a filling of the tubules with free nuclei. He further supposes that the nuclei of the proliferated epithelium become converted into spindle cells and connective tissue. (See reports of the above meeting in *Lancet* and *British Medical Journal*, March 27, 1880.) So far as I understand the report of his statements, he is of opinion that the proliferated epithelial nuclei traverse the basement membrane of the tubules, and thus migrate into the stroma, where they undergo fusiform and fibrillar changes leading to true fibrous increase of the interstitial tissue.

This supposed fibrous histogenesis from proliferated epithelium is so remarkable that it appears to merit a few words of independent consideration, before we proceed to discuss the question as to how far it may coincide with the early interstitial appearances of the stroma as seen in glomerulo-nephritis. The idea, though strange, is by no means new. Holm (*Wiener Acad. Sitzungsb.* 1867), Dr Wickham Legg (*Barth. Hosp. Reports*, 1872), MM. Kiener and Kelsch (*Arch. de Phys.* 1879), and Mr D. J. Hamilton (*Journ. Anat. and Phys.* Jan. 1880), have attempted to

establish an analogous origin of the fibrous tissue of cirrhotic liver from the nuclei of the hepatic cells, and Dr Creighton has also recorded certain indications of a like process of connective-tissue formation in the mamma. Mr Hamilton, more especially, expresses himself with great confidence respecting the origin of the fibrous tissue in hepatic cirrhosis, for he says :—

"The absurdity of tracing the origin of the cirrhotic fibrous tissue to exuded leucocytes, as has been affirmed but never demonstrated by a certain school of pathologists, only requires for its detection a little unbiassed observation."

Accordingly, he thus summarises the results of certain observations conducted by himself :—

"(*a*) The liver cells are one of the main sources of the fibrous tissue developed in the organ.

"(*b*) The first visible change in their transformation is the enlargement of the nucleus, and the development of a nucleolus and intranuclear plexus. The enlarged nucleus then divides, and this is almost simultaneously followed by transverse fission of the whole cell.

"(*c*) Two smaller cells thus arise, each having a nucleus, and these nuclei soon grow to as large a size as that from which they sprung.

"(*d*) The periplast, however, does not increase in size *pari passu*, but at each successive division becomes smaller and smaller, until finally nothing but a free nucleus remains.

"(*e*) This free nucleus now enters upon a new existence. It becomes oval, and from its free border a fresh periplast is generated, which assumes a fusiform shape.

"(*f*) The fusiform or spindle-shaped periplast now splits into a number of fibrils, and becomes more elongated and tapering at the extremities. The ultimate result is the formation of a bundle of white fibrous tissue out of these fibrils, the nucleus remaining on the surface as the nucleus of the bundle."

I regret that it is somewhat foreign to the scope of the present paper to enter into a detailed examination of the grounds on which Mr Hamilton relies in support of his theory. One or two points, however, seem to call for passing remark, in order that

we may clearly comprehend all the issues involved in the question.

Firstly, It is a recognised fact that the nucleus of a disintegrating cell is by far the most resistant of the cell constituents; hence, long after cells have become disintegrated, the nuclei remain behind in a free state, and are apparently but little altered, save that in many instances their capacity for absorbing vegetable colouring matters is materially increased. This fact is observable in the kidney, as well as in the liver, and in the former organ is sometimes extremely characteristic, much more so, according to my experience, than in the latter. For instance, in a section of kidney we often meet with tubules in transverse section, whose lining epithelium has entirely disappeared save for the still persistent nuclei, which are yet visible, clinging to the inside wall of the basement membrane. Their power of absorbing staining fluids is remarkable, and at times perfectly diagrammatic.

The same appearance is observable in the nuclei of the epithelial investment of the glomeruli, more especially in those glomeruli which are becoming homogeneous, hyaline, or colloid, from incipient degenerative changes. This last fact is very significant, and seems to point to commencing degeneration as a cause of the heavy coloration, and not, as Mr Hamilton supposes in the case of the liver cells in which he has observed a similar phenomenon, to the entry of the nucleus upon a new stage of existence. On the contrary, it seems rather to herald the approach of impending dissolution.

Further, after an examination of many hundreds of sections taken from an extensive series of specimens of interstitial nephritis, I have never seen an instance of any approach to fusiform or fibrillar transformation in the deeply-stained nuclei adherent to the inner surface of the basement membrane of tubules whose epithelium has become disintegrated. The nuclei were invariably found to retain their pristine form, nor did they ever exhibit the least appearance of formative activity. Surrounded by the intact and much-thickened basement membrane, they seemed to be quietly awaiting their euthanasia. In the similar process of hepatic cirrhosis, the liver cells become disintegrated and disappear in the same way, and from very much

the same causes as those at work in the interstitial kidney, namely, interference with blood supply, and direct pressure, leading to impairment of vitality and function. Just as in the kidney, their nuclei are the last elements to undergo disintegration; and, consequently, we frequently meet with aggregations of free nuclei in the midst of surrounding cirrhotic bands as figured by Mr Hamilton (*Journ. Anat. Phys.* Jan. 1880, pl. viii, fig. 1), these nuclei being identical in nature and appearance with the nuclei of other cells whose protoplasm is still more or less intact. They also somewhat resemble the elements of the small-cell infiltration in portions of cicatricial tissue which have not yet become fusiform or fibrous, but differ from them in the crowded manner in which they are huddled together by the surrounding process of contraction, and also in their larger size, denser appearance, and greater depth of coloration. They are, in fact, the few survivors of the once numerous army of liver cells, and are quite insignificant in numbers compared with the total bulk of new cicatricial tissue, whose final and fatal contraction upon them they are passively awaiting.

Sometimes a very few of these nuclei appear to have been mechanically compressed into an approximate spindle shape, but of these I have never seen more than perhaps a dozen at the most liberal computation. When isolated they appear to be destitute of protoplasm, mere naked nuclei with no indication of intranuclear plexus, so far as my observations extend.

In the liver, however, a certain dubiety as to the nature and condition of these nuclei may possibly be feasible, on account of the identity of their anatomical site with that of the small-cell infiltration; but in the kidney this doubt is removed, for the basement membrane of the denuded and atrophied tubules containing them is not disintegrated but thickened, and they are thus unmistakably marked off and separated from the surrounding intertubular round-cell infiltration. The cells of the latter evince formative and differentiative activity, whereas the nuclei exhibit no changes of shape, and are evidently inert and passive.

Secondly, A strong inferential argument is afforded against the hypothesis of the histogenesis of a new pathological tissue from the nuclei of a disintegrating normal one, if we consider that adherence to this doctrine must perforce necessitate the

alteration of all our now well-established ideas as to the active portion of the cell constituents. It is no mere hypothesis that the protoplasm and not the nucleus is the active element of the normal animal and vegetable cell; nor is it less certain that the phenomena of disease involve no new vital processes, either structural or functional, which are distinct in kind, and have not their antitype and analogue in certain corresponding normal ones. This is, in fact, one of the fundamental laws of modern pathology; so that the admission of the histogeny of a diseased tissue from the nuclei of a disintegrating normal one implies the inevitable corollary of the histogeny of new normal tissues from the nuclei of previously existing disintegrating ones. There is not a single process of abnormal tissue formation which is radically and essentially distinct in kind from all normal ones, for both normal and diseased processes are alike manifestations of the vitality and functional activity of the tissues; the only difference being that the former are indications of life under favourable conditions the latter under unfavourable. If this be not so, the principles of modern pathology are radically false. Those principles, however, will hardly be overturned by the presumptive evidence of a few isolated specimens. Probability would rather incline towards a possible erroneous interpretation of the appearances observed in the specimens in question.

Thirdly, In the case of the liver, the histogenesis of fibrous tissue from the hepatic cells would appear to involve a breach of the embryological law of Remak. Mr Hamilton attempts to overcome this objection by assigning a mesoblastic origin to the liver cells. He considers it probable that the branching cylinders of cells in the embryonic organ are developed from the mass of the mesoblast which gathers around the sac-like offshoots from the primitive duodenum. This is, of course, possible, for I am fully aware of the difficulties attending the discovery of the exact embryonic source of the tissues of the abdominal organs. Of course nothing save renewed embryological investigations of the most careful nature can definitely settle the question; but, in the meantime, Mr Hamilton's hypothesis, though agreeable to the conclusions of Schenk, runs counter to the researches of the principal modern embryologists. Among these we may cite the authority of Foster and Balfour, who state that the cellular

elements of the liver are derived from the hypoblast, the mesoblastic portions being mainly differentiated into the blood-vessels, and the fibrous tissue of the ducts. This objection does not, of course, apply to the kidney, in favour of whose mesoblastic origin there is a general consensus of opinion on the part of the principal modern observers.

Let us, however, see how far the supposed origin of the fibrous increase in the interstitial stroma of the granular kidney from the nuclei of the tubular epithelium agrees with the facts observed in my early specimens of interstitial lesions. Patches of interstitial cell-infiltration were observed in their initial stages in all my specimens of glomerulo-nephritis. In the one last described the round-cell infiltration was in process of conversion into the familiar fibrous tissue of interstitial nephritis, so that, by the help of this transitional example, I am enabled to trace with tolerable certainty the course of the changes which result in the development of the ordinary forms of granular kidney.

In the common forms of this lesion we observe that the fibrotic substance is most abundant around the Malpighian capsules, along the path of the vessels of the general stroma, and immediately under the capsule, where it forms cicatricial bands running into the cortical substance and firmly binding the capsule to its periphery. Now, *it is precisely in these situations that abundant accumulations of unmistakable leucocytes* are seen in glomerulo-nephritis. In the delicate perivascular tissue around the vessels of the stroma, numberless leucocytes are seen aggregated in dense masses, immediately outside the vessels from which they have migrated. When we add that the general tubular epithelium is quite normal save for the sporadic foci of fatty and granular change in the immediate neighbourhood of the Malpighian bodies to which we have already alluded, the conclusion appears inevitable that the fibrous patches of the later stages of interstitial kidney are the lineal descendants of these masses of leucocytes,—nay, the very leucocytes themselves, which have undergone fibrous differentiation.

Therefore the "absurdity of tracing the origin of the cirrhotic fibrous tissue to extruded blood leucocytes" does not, at least in the case of the kidney, appear so very glaring.

Explanation of Plate XXVII.

Fig. 1 (× 300). A Malpighian body from the kidney, in the early stage of glomerulo-nephritis. The glomerulus is obscured by a small cell accumulation. Bowman's capsule is thickened at one portion of its circumference, and contains a few round cells. A similar cell-infiltration is beginning in the stroma immediately around it. The uriniferous tubules and their epithelium are still normal.

Fig. 2 (× 50). Glomerulo-nephritis as seen with a low power. The Malpighian bodies appear enlarged and prominent, and look as if sprinkled with fine sand. The tubules are normal, but the small arteries are surrounded by a dotted margin of migrated cells. An accumulation of these cells is beginning in the stroma immediately under the general capsule.

Fig. 3 (× 400). A glomerulus which has undergone complete fibrous transformation. The capillary loops are blended with their investing capsule, and are completely impervious. The small cells on the surface of the glomerulus are much diminished in number. The epithelium of the uriniferous tubule communicating with the fibrous Malpighian body is fatty. A neighbouring tubule contains leucocytes, and its epithelium is undergoing granular disintegration. The whole Malpighian body is shrunken and diminished in size.

Fig. 4 (× 400). A Malpighian body with thickened capsule and shrunken semifibrous capillary loops. The round cells on the surface and in the substance of the glomerulus are diminished in number, though not so much as in fig. 3. Outside the thickened capsule are a number of round cells.

Fig. 5 (× 250). An arteriole from the stroma of the cortex, surrounded by a dense accumulation of migrated leucocytes. The coats of the vessel are normal. A capillary communicating with it contains a number of leucocytes.

Fig. 6 (× 400). A fibrous glomerulus, impervious, and united with its thickened capsule. To the outside of the capsule is a dense accumulation of round cells, while those on the surface of the glomerulus are not numerous. Three tubules, close to the affected Malpighian body, contain fatty epithelium which is stained deep black with osmic acid. Another tubule is completely denuded of its epithelium.

Fig. 7 (× 300). A Malpighian body from the kidney of the boy who died in the Aberdeen Infirmary. The glomerulus is much shrunken, occupying not more than half the space in the interior of its capsule, which is thickened and fibrous. A few epithelial-like bodies are seen in the otherwise empty space inside the capsule. The interstitial stroma around the Malpighian body is thickened and fibrous. The uriniferous tubules are denuded of epithelium, and a few are compressed and shrunken.

Fig. 8 (× 300). A Malpighian body entirely hidden by a dense accumulation of small cells.

THE ANTAGONISM OF OPIUM AND BELLADONNA, ILLUSTRATED BY A CASE OF ATTEMPTED SUICIDE. By J. GOODALL NAISMYTH, M.B., *Foulford, Cowdenbeath, Lochgelly.*

THE following case illustrates the antagonistic action of Opium and Belladonna in the human subject. I was sent for whilst in the village of Fordel to see a woman said to be very ill. On visiting the house I found the woman in bed, apparently sleeping. The smell of whisky was strong in her breath. I asked if she had been drinking, and was informed that she had about three glasses of whisky between two o'clock and the time I saw her—five o'clock. The breathing was slightly stertorous, pulse very weak, skin warm and moist, face livid and gorged. On examining pupils, found they were dilated and insensible to light. The symptoms struck me as being those of narcotic poisoning, and by inquiry found that a quantity of laudanum had been swallowed, probably five or six drams. I endeavoured to excite vomiting, without effect; also endeavoured to rouse the patient by dashing cold water over chest and face, and by moving her about, but all without the very slightest effect. Several points struck me as peculiar; first, the dilated pupils, and second, notwithstanding the profound insensibility, the breathing was very regular and easy. I asked the question if there were any other drugs in the house, and found that a bottle containing a solution of two grains of sulphate of atropia to half ounce of water was empty, and it had been previously full. Here was an explanation to those important symptoms, and a guide to the treatment.

Another point in the case of importance was, that notwithstanding the general muscular relaxation, there was rigidity of the muscles of the jaw, so that the mouth could not be opened to any extent. An important question to decide was whether it was better to leave the case alone, or by forcible measures endeavour to remove the contents of the stomach. If it had been possible, I do not think the case would have terminated so favourably as it did, as the proportion of solution of atropia was at least one to twelve; and even although the stomach had been

almost emptied by artificial means, we could still imagine as much atropia left as would prove fatal from belladonna poisoning alone, the opium having been removed.

The body becoming cool, I ordered hot bottles to the feet and sides, and enemata of milk and coffee to be given every hour or so, and this was the only treatment adopted. Under these measures the patient gradually came out of the comatose state she was previously in, and vomited a quantity of fluid. Milk and coffee were then given by the mouth, and in the course of the following day the patient was pretty well, only nervous and easily alarmed.

REMARKS.

The action of belladona and opium are so well known that I do not need to refer to it, only to bring the evidence to bear on my case.

1. *The state of Respiration.*—In opium poisoning, of course, this is the most dangerous symptom—the patient generally dying from failure of respiration. In my case, the respiration gave me no concern, as it was carried on quite well. I remember another case of fatal opium poisoning, where I continued artificial respiration for about six hours, and only kept the patient breathing by the most tedious endeavours, finally to be disappointed.

In this present case the respiration, I believe, was kept up by the atropia.

2. *State of Pupil.*—The rule is, of course, that the pupil is contracted in opium poisoning, but it may be dilated, or one contracted and the other dilated, as mentioned in Taylor's *Medical Jurisprudence.* But in a case like mine, where the dose of opium was pretty large, a state of contraction was the result to expect, but the atropia seemed to counterbalance this action on the pupil.

3. *State of Muscles of Jaw.*—I do not know why this should have occurred, the action of both opium and belladonna on the muscular system being to produce relaxation and relieve spasm, instead of causing it.

4. The action of the alcohol taken must be taken into account, and its stimulant effect on the heart and circulation must have had a great effect in the rècovery of the woman.

I do not think that the two antagonistic drugs could have acted in their various ways, however antagonistic they are in some points, if there had not been a cardiac stimulant, as the whisky was.

5. Another important point. She vomited (about eight hours after having taken the drugs) both whisky and laudanum,—judged by their smell, and doubtless also the atropia. This shows that the action of the stomach is retarded by narcotism. Absorption only takes place to a limited extent, and emetics or stomach-pump can do good long after opium has been taken.

... AN ASTRAGALO-SCAPHOID BONE

... R. J. ANDERSON, M.D., *Demonstrator of* ... *lege, Belfast.*

... 34. The lower extremities are well ... are small and well shaped. When the soft ... were removed, the carpus consisted of six ... astragalo-scaphoid, os calcis, cuboid, and three cunei- ... astragalo-scaphoid has an upper surface which is ... and non-articular in front. The articular ... rather more than half of the upper surface, it ... behind than in front. The outer margin is more ... the inner. The anterior and outer angle of the ... by a vertical plane. This causes the anterior ... quarter of an inch narrower than the transverse ... of the surface half an inch farther back. The ... portion of the upper surface is non-articular, and in ... the head of the bone; it is convex from side to ... perforated by numerous foramina. The posterior ... the markings usually observed on the posterior ... the astragalus. The external surface is partly arti- ... partly non-articular. The articular part forms a trian- ... with which the fibula articulates. The lower part of ... is bent outwards, so that the surface looks upward as ... outwards. The anterior part of the external surface is ... and corresponds to the outer portion of the neck, ... however, is not so well marked as in the astragalus. ... surface has a pyriform articular facet, such as the ... possesses. A rough surface is situated below, and a ... surface in front of this. The inner articular ... is more prominent than that on the outer side of the

... inferior surface has a large facet behind, which is con- ... from side to side, and articulates with the facet on the ... surface of the os calcis. In front of this and corresponding ... third of the inferior surface is a rough depression. ... this depression a small elevated facet is ... a quarter of an inch from side to side,

and two lines from before backwards. This articulates with the facet on the upper surface of the sustentaculum tali. In front of the rough depression is the lower surface of the head, which is broader from side to side than from before backwards. The surface is flat. The upper surface of the head of the astragalo-scaphoid is convex from side to side and rough. The inner surface is rough and non-articular; the outer surface possesses a facet for articulation with the cuboid. This facet encroaches upon the inferior surface. The inferior surface is partly articular and partly non-articular. The inner two-thirds is rough and non-articular, the outer third is articular and is occupied by the facet for the cuboid. The anterior surface is articular and has three facets, each wider above than below. Ridges separate these facets one from the other and the outer facet from that for the cuboid. The anterior surface is convex from side to side and from above downwards, and has a small non-articular part near the middle of the lower border. Thus the long diameter of the anterior articular surface is from side to side, the short diameter from above downwards, its inferior border convex, its lower border slightly concave. The outer extremity of the head is thicker than the inner.

The os calcis does not differ much from the ordinary condition of this bone. The upper surface is partly articular and partly non-articular. The large posterior facet for the astragalus is convex from before backwards and from within outwards. In front of this surface is a rough depression which is narrow internally and behind, and so wide externally as to occupy the whole of the anterior portion of the upper surface. This surface gives attachment to the interosseus ligament posteriorly. Surmounting the sustentaculum tali is a facet which articulates with a corresponding facet on the astragalus. This facet is separated from the large posterior facet on the upper surface by a groove. The anterior surface is double curved, and articulates with the cuboid. The remaining surfaces present no features of interest.

The head of the astragalo-scaphoid is received into a cavity formed by the three cuneiform and the cuboid. The articular surface on the inner part of the latter b[illegible] and is placed edge to edge with the articular f[illegible] terior

THE PRESENCE OF AN ASTRAGALO-SCAPHOID BONE IN MAN.

By R. J. ANDERSON, M.D., *Demonstrator of Anatomy, Queen's College, Belfast.*

IN a male subject, aged 34. The lower extremities are well formed. The feet are small and well shaped. When the soft parts of the right foot were removed, the carpus consisted of six bones—the astragalo-scaphoid, os calcis, cuboid, and three cuneiform. The astragalo-scaphoid has an upper surface which is articular behind and non-articular in front. The articular portion occupies rather more than half of the upper surface, it is narrower behind than in front. The outer margin is more prominent than the inner. The anterior and outer angle of the bone is cut off by a vertical plane. This causes the anterior border to be a quarter of an inch narrower than the transverse measurement of the surface half an inch farther back. The anterior portion of the upper surface is non-articular, and in front reaches the head of the bone; it is convex from side to side, and perforated by numerous foramina. The posterior surface has the markings usually observed on the posterior surface of the astragalus. The external surface is partly articular and partly non-articular. The articular part forms a triangular facet with which the fibula articulates. The lower part of the surface is bent outwards, so that the surface looks upward as well as outwards. The anterior part of the external surface is non-articular and corresponds to the outer portion of the neck, which, however, is not so well marked as in the astragalus. The inner surface has a pyriform articular facet, such as the astragalus possesses. A rough surface is situated below, and a large rough surface in front of this. The inner articular surface is more prominent than that on the outer side of the bone.

The inferior surface has a large facet behind, which is concave from side to side, and articulates with the facet on the upper surface of the os calcis. In front of this and corresponding to the middle third of the inferior surface is a rough depression. At the centre of this depression a small elevated facet is situated. It measures a quarter of an inch from side to side,

and two lines from before backwards. This articulates with the facet on the upper surface of the sustentaculum tali. In front of the rough depression is the lower surface of the head, which is broader from side to side than from before backwards. The surface is flat. The upper surface of the head of the astragalo-scaphoid is convex from side to side and rough. The inner surface is rough and non-articular; the outer surface possesses a facet for articulation with the cuboid. This facet encroaches upon the inferior surface. The inferior surface is partly articular and partly non-articular. The inner two-thirds is rough and non-articular, the outer third is articular and is occupied by the facet for the cuboid. The anterior surface is articular and has three facets, each wider above than below. Ridges separate these facets one from the other and the outer facet from that for the cuboid. The anterior surface is convex from side to side and from above downwards, and has a small non-articular part near the middle of the lower border. Thus the long diameter of the anterior articular surface is from side to side, the short diameter from above downwards, its inferior border convex, its lower border slightly concave. The outer extremity of the head is thicker than the inner.

The os calcis does not differ much from the ordinary condition of this bone. The upper surface is partly articular and partly non-articular. The large posterior facet for the astragalus is convex from before backwards and from within outwards. In front of this surface is a rough depression which is narrow internally and behind, and so wide externally as to occupy the whole of the anterior portion of the upper surface. This surface gives attachment to the interosseus ligament posteriorly. Surmounting the sustentaculum tali is a facet which articulates with a corresponding facet on the astragalus. This facet is separated from the large posterior facet on the upper surface by a groove. The anterior surface is double curved, and articulates with the cuboid. The remaining surfaces present no features of interest.

The head of the astragalo-scaphoid is received into a cavity formed by the three cuneiform and the cuboid. The articular surface on the inner part of the latter bone is large, and is placed edge to edge with the articular facet on the posterior

part of the external cuneiform. The articular surface of the internal cuneiform is deeply concave, the posterior articular surface of the middle and external cuneiform much less so. The articular facet of the cuboid is concave, and separated by a ridge from the articular facet for the external cuneiform. Almost the entire external surface of the cuboid is therefore articular.

The cuneiform, cuboid, metatarsal, and phalangeal bones present the usual characters.

The left foot possesses likewise six tarsal bones, the astragalus and scaphoid having coalesced to form a single bone. The general characters are those of the astragalus and scaphoid united, with such slight deviations from the form as exist in the right lower extremity. No line of division, however, shows a trace of a previous separation into two bones, and no external signs of any pathological changes are present.

A section of the left astragalo-scaphoid made from before backwards shows that the cancellous tissue resembles that of the astragalus.

An increase or diminution in the number of bones in the carpus and tarsus, though somewhat unusual, has been observed by several anatomists. In the carpus nine bones have been observed, the place of the scaphoid has been occupied by two bones, the semilunar has been replaced by two, an anterior and a posterior (Smith), and the internal cuneiform in the foot by two. A ninth bone is stated by Meckel to exist sometimes between the os magnum and the trapezoid.[1] The radial portion of the scaphoid may be regarded as a radial scaphoid, an os centrale, or as a portion of the scaphoid which represents the os centrale.

In the hand the cuboid and semilunar have been found united (R. Wagner);[2] in the foot the calcaneum and cuboid, calcaneum and scaphoid, and second and third cuneiform bones. Bones of the sesamoid variety are occasionally found[3] in connection with the carpus and tarsus, and the styloid process of the third

[1] Humphry, *A Treatise on the Human Skeleton*, p. 80.

[2] Heusinger's *Zeitschrift*. t. iii. p. 300. Referred to by Professor Humphry in *op. cit.*

[3] Humphry, *op. cit.* p. 80.

metacarpal has been found as a separate ossicle in several instances.[1]

In Carnivora, Cheiroptera, and many rodents (*Mus*, *Castor*, *Hydrochœrus*), and in many insectivors, a scapho-lunar bone is present. In pteropus of the Cheiroptera, the cuneiform unites with the scapho-lunar in the foot.[2]

In Crocodilia the scaphoid and astragalus coalesce to form an astragalo-navicular bone. In the Chelonia, whilst in the hand we have nine ossicles, in the foot of chelone, emys, testudo, and trionyx the centrale is united with the astragalus, and in emys the calcaneum coalesces into the astragalus.[3]

In reviewing, therefore, the various conditions of the bones of the tarsus in vertebrates, it is seen that the os centrale is found united with the cuboid (tragulina and pecora) with the astragalus (chelone), and in some cases the calcaneum is added (emys).

In the carpus, the scaphoid and lunar unite (Carnivora), scaphoid-lunar and cuboid (pteropus), scaphoid and trapezium (sloth and megatherium).[4]

In comparing the bones of the carpus and tarsus, the astragalus may be regarded as the homologue of the lunar (Vicq d'Azyr), or as corresponding to the united scaphoid and semilunar (Gegenbaur). The scaphoid in the foot, on the other hand, may be regarded as equivalent to the scaphoid in the hand, or to a portion of the scaphoid, the radial portion (of Gruber),[5] or, lastly, as having no single portion of bone representing it in the human carpus. The presence of the divided scaphoid in the case of man, the radial portion of which corresponds to the position of the os centrale of the Quadrumana would seem to favour the second idea.

In the case noted above the astragalo-navicular would then be the homologue of the scapho-lunar bone of the carpus of Carnivora. And the case given by Wagner of the union of the semilunar and cuboid would approach the condition found in the carpus of pteropus, and be similar to the condition in the tarsus of certain of the Lacertilia.

[1] Gruber, *Beobachtungen aus der Menschlichen und Vergleichenden Anatomie*, Heft ii. p. 37.

[2] Flower, *Osteology of Mammalia*.

[3] Hanley, *Anatomy of Vertebrates*, p. 200.

[4] Owen, *Nature of Limbs*.

[5] *Virchow's Archiv*. Band lxxiv. p. 433.

ON THE MODE OF HEALING IN WOUNDS UNDER ANTISEPTIC DRESSINGS. By DAVID FOULIS, M.D., *Pathologist to the Royal Infirmary, Glasgow.*

IN this paper I propose to describe the changes in progress in an antiseptic wound healing without suppuration, with a blood clot lying between the lips of the wound and apparently organising. The case was that of a boy aged five years, on whom osteotomy was performed by Dr Macewen in January 1880. The wound healed steadily, but the boy succumbed to an attack of diphtheria, which began on the fifth, and proved fatal on the twelfth day after the operation. On *post-mortem* inspection I found caries of the 1st and 2d cervical and 4th lumbar vertebræ, with suppuration at both of these places; false membrane coating the fauces, larynx, and trachea; swelling of the lymphatic glands in the vicinity of the pharynx; and some congestion of various viscera. There was a small nearly healed wound ½ inch long, seated about 1½ inch above the lower end of the internal condyle of the left femur; this wound had been stitched with catgut, the knot of one of the stitches being still *in situ*. In the subcutaneous tissue beneath the wound was a small reddish brown blood clot extending in the form of dark red blood clot along the intermuscular septa and connective tissue bundles. There was no blood below the periosteum, which had been divided opposite to the cutaneous wound, where also the shaft of the femur had been cut straight across (½ inch above the epiphysal cartilage); a little blood clot lay between the cut surfaces of the bone. The periosteum was intact, except on the internal aspect of the bone. The case was complicated by the occurrence of the diphtheritic disease in the throat, but no trace of implication of the wound could be discovered, nor have I any reason to suspect that the wound itself ran a different course from the average antiseptic wound. It presented to the naked eye the characteristic appearance of such a wound, in which a blood clot separating the edges had slowly become vascular, and then paler on the surface, until it seemed to be transformed into scar tissue. It was interesting to discover what the change had been due to;

and the case was the more valuable, as patients rarely die with so small an antiseptic wound at this early stage; while, also, the minute changes were those in the human subject, and not in a lower animal, in which some difference might be looked for. I removed the wounded part, therefore, very carefully *en bloc*, and placed it in absolute alcohol. As soon as it was sufficiently hardened I made with the razor a series of transverse sections to display every part of the wound; which sections were coloured with logwood, and mounted in gum-damar, so as clearly to show out the untinted red blood cells and debris against the purple cells and tissue round them.

The wound had healed over at both ends, and there the rete malpighi and squamous layers (fig. 3) were quite visible, though devoid of subjacent papillæ, the dermis being represented by a layer of spindle-celled tissue. Below this spindle-celled tissue lay the extravasated blood spread out along the connective tissue septa. Towards the centre of the wound the picture was different. Here the blood-clot and adipose tissue lay quite close to the surface, protected only (fig. 1) by a thin layer of round cell tissue, over which in places the epithelial layer appeared (fig. 2) to be spreading from the edges of the wound. The blood cells in the clot were quite intact up to its very edge, where the red cells had become broken down into debris. All round every part of the blood-clot (figs. 1 and 4) was a layer of cells which closely resembled granulation cells, and many of these cells had infiltrated the clot. In the tissues round the clot there was an abundant cell growth, which decreased as one went further from the clot, and at a short distance from it was no longer seen. Under a high power these cells which lay in the edge of the clot and near it were seen to be full of yellow granules, like the debris of the blood cells, as if they were actively taking up this debris. It was evident, on careful inspection of every part of the clot, that it was slowly diminishing and breaking up as the cell growth advanced, and that it was not taking any share in the organisation, except as a mould on which the new tissue might feed and form. It was encased, in fact, in a layer of round-celled tissue, which I will call granulation tissue; and this differed in no respect from ordinary granulation tissue in antiseptic wounds (selected for comparison), save in its *great*

FIG. 2.

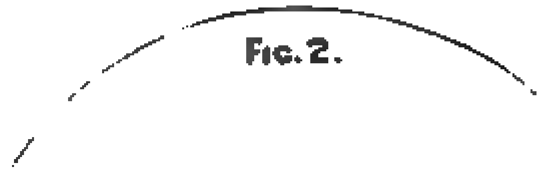

FIG. 1.—(Low power; about 80 diam.) Transverse vertical section across centre of wound, showing the blood clot (shaded) lying below a coating of granulation tissue, which also covers over (at M) the exposed fat cells. The fat cells and septa round the blood clot are infiltrated with round cells, and the clot itself is encased and penetrated by similar round cells.[1]

FIG. 2.—(Power of say 300 diam.) A part (M) of the same section as in fig. 1 under a higher power, showing how the fat cells are encased and covered in by round celled tissue, which in turn is being coated over by an advancing layer of epithelial cells, spreading from the edges of the wound.

FIG. 3.—(Power of 300 diam.) Section from the healed end of the wound, in which the rete malpighi and the squamous layers are seen restored; but the dermis replaced by a spindle-celled tissue devoid of papillæ.

FIG. 4.—(Power of say 500 diam.) Shows the edge of the blood clot, with the new (granulation?) round cells infiltrating it. The blood cells of the clot (at the left of the drawing) are breaking up into debris, which is being taken up by the round cells. Close to the clot these round cells are full of yellow granules.

[1] These cells are not shown in this woodcut in sufficient number.

tenuity, and in the *entire absence of suppuration*. It was a typical picture of perfectly healthy granulations, free from any sort of abnormal irritation, with the cell growth kept down to a minimum, and every cell in the granulations utilised for the healing process, no cells being thrown off and lost as pus. Whether the cells which formed this new tissue were derived from leucocytes alone, or, as I think, from an irritative nuclear growth in the tissues near the clot as well, I will not here discuss; it is sufficient for my purpose to indicate the very close resemblance to granulation tissue, if not indeed complete identity with it.

If this be a true picture of the progress of union of antiseptic wounds, as I have no doubt it is, then the process is essentially healing by granulation without suppuration, and it is not an "organisation of blood clot." I am aware that in some aseptic effusions of blood—*e.g.*, on the lining of the dura mater—there is an attempt at organisation of blood clot.[1] The clot in such cases is soon channelled by a network of blood capillaries; a certain proliferation of leucocytes in it goes on, and the fibrin of the clot becomes denser and more distinctly fibrillated. But soon the blood channels are obliterated, the cell growth ceases, and after months or years we have a pale tough layer of altered fibrin, in which the former course of the blood channels is marked out by granules of hematin. Such a half-organised layer may exist possibly in some antiseptic wounds also, and may remain for years in the tissues. But if the case above described is not deceptive in some way, the closure of the wound and the real cicatrisation is usually carried on by a thin layer of granulation tissue, which surrounds and covers in the clot, and gradually destroys it.

A point of some interest still remains unsettled—viz., whether under any circumstances epithelial cells may, without the intervention of what I have called granulation tissue, creep over and cover a tissue, be it tendon or adipose tissue, or blood clot, &c., which has been exposed under antiseptic conditions *in the human body*. Some surgeons affirm that they have seen this, and certainly, to the naked eye, it looks as if in certain wounds the exposed tissues became covered in by epithelium directly.

[1] See paper by me in *Edin. Med. Journal*, May 1877, "On the Behaviour of Blood Clot in Aseptic Conditions."

But hitherto the specimens which I have been able to examine microscopically have all showed that a very thin layer of round-celled tissue precedes the layer of epithelial cells. That layer may not be visible as a distinct granulation tissue to the naked eye, but nevertheless I think I am justified in giving it that title, and in affirming the type of the healing of antiseptic wounds to be essentially that by granulation modified by the absence of irritation.

ON THE RESPIRATORY MOVEMENTS OF FISHES (No. 1.) By Professor M'KENDRICK, *University of Glasgow*. (PLATE XXVIII.)

1. In the course of some investigations on the conditions of aquatic respiration,[1] I counted the number of movements of the gill-covers of fishes per minute, and noted also the character of the movement. It soon became evident even to the eye that the movements in various species of fishes were often different, both as regards rhythm and character. This led to an attempt to obtain a graphic registration of these movements, and after overcoming several experimental difficulties, I at last succeeded in devising a method by which a tracing can be obtained.

2. At first I tried the plan of laying the fish on its side in a cavity full of water, in a thick plate of vulcanite. It was easy to keep a supply of water circulating around the fish. A light lever was placed on the gill-cover, and the movement communicated directly to the surface of a blackened cylinder. This method, open to many objections, more especially the unnatural position of the fish, and the possible interference with the movement of the gill on the under-side of the fish, was soon abandoned. Next, I made use of an arrangement of Marey's tambours, and after some practice with it, I found no difficulty in transmitting very delicate movements from the gill-cover, whilst the fish was in its natural position. I place the fish in its natural position in a narrow trough of lead, 16 inches in length, 4 in breadth, and 4 in depth, and arrangements are made for keeping up a constant stream of water. To keep the fish in position (if it be a small one) long pieces of cotton-wool or yarn are sometimes placed around it, and usually it does not require to be held. A fish will often remain motionless if the simple expedient be adopted of laying a mass of wet cotton-wool over its eyes. Sometimes a fish may be very restless, and it may be difficult to get a continuous tracing for more than half a minute at a time. The tracing is obtained as follows:—A stand is placed beside the trough bearing a series of arms, having adapting screws, and to one of the arms a small tambour is attached. By means of

[1] Being carried out with the assistance of a grant from the Royal Society.

the arms and screws, movement in any direction is secured. Attached to the lever of the tambour there is a flat plate of metal or "button," about a quarter of an inch in breadth. An india-rubber tube, about 4 feet in length, passes from this tambour to another tambour, and by the movement of the lever of the latter a tracing is obtained on a cylinder moving horizontally. When ready for the experiment, the transmitting tambour is so adjusted that the button comes into contact with the gill-cover, pressing upon it very gently, and by means of fine adjustment screws, the pressure can be regulated until the lever of the recording tambour is seen to move freely. The latter is then brought down upon the surface of the cylinder and a tracing is obtained. Frequently the fish in making a struggle, or in attempting to turn round, may disarrange the apparatus, and adjustments must be again made before taking a fresh tracing. The advantages of the method are that the fish is in a natural position, and under no undue restraint, and there is no excess of pressure on the gill-cover, which is allowed to move freely. A chronographic tracing is taken at the same time, a metronome interrupting the current three times in a second.

3. By the method above described, I have taken tracings from the following fishes:—Tench (*Tinca*), Perch (*Perca*), Pike (*Esox*), Fresh-water Eel (*Anguilla*), Loach (*Cobitis*), Dace (*Leuciscus vulgaris*), Minnow (*Leuciscus phoxinus*), Prussian Carp (*Cyprinus gebelio*), Gold Carp (*Cyprinus auratus*), Whiting (*Merlangus*), Cod (*Morrhua*), Saithe (*Merlangus carbonarius*), Flounder (*Platessa*), Herring (*Clupea*), Dog-fish (*Acanthias*), John Dory (*Zeus*), Rockling (*Motella*), Wrasse (*Labrus*), Lump-fish (*Cyclopterus*), and Stickleback (*Gasterosteus*). For specimens of the tracings, see Plate XXVIII.

4. The tracings are to be read from right to left in the direction of the arrows. The down-stroke, marked by the small arrow *a*, is in all cases the line made by the point of the recording lever when the gill was opened; and the up-stroke, marked by the small arrow *b*, represents the movement when the gill was closed. The time occupied by a complete respiratory movement is indicated by the distance between the points *c* and *d* in tracing No. 1, and so with regard to all the other tracings, except No. 10. This time may be measured by the chronographic scale No. 23.

5. The following table shows the rate of the respiratory movements in these fishes:—

No. of tracing in Plate.	Name of Fish.	Length of Fish in inches.	Time occupied by one respiration in thirds and sixths of a second.	Number of respirations per minute.
1.	Tench, . . .	12	$\frac{4}{3}$	45
2.	Perch, . . .	6	$\frac{3}{3}+\frac{1}{6}$	51
3.	Pike, . . .	14	$\frac{5}{3}$	36
4.	Fresh-water Eel, .	24	$\frac{5}{3}+\frac{1}{6}$	32
5.	Loach, . . .	3	$\frac{2}{3}$	90
6.	Dace, . . .	4	$\frac{2}{3}+\frac{1}{6}$	72
7.	Minnow, . .	2	$\frac{1}{3}+\frac{1}{6}$	120
8.	Prussian Carp, .	3	$\frac{4}{3}+\frac{1}{6}$	40
9.	Golden Carp, .	6	$\frac{3}{3}$	60
11.	Whiting, . .	12	$\frac{6}{3}+\frac{1}{6}$	27
12.	Cod, . . .	14	$\frac{5}{3}$	36
13.	Saithe, . . .	11	$\frac{4}{3}$	45
14.	Flounder, . .	7	$\frac{4}{3}+\frac{1}{6}$	40
15.	Herring, . .	7	$\frac{2}{3}$	90
16.	Dog-fish, . .	14	$\frac{5}{3}$	36
17.	John Dory, . .	8	$\frac{8}{3}$	22
18.	Rockling, . .	10	$\frac{12}{3}$	15
19.	Common Wrasse, .	11	$\frac{3}{3}$	60
20.	Blue Wrasse, .	9	$\frac{12}{3}$	15
21.	Stickleback, . .	$2\frac{1}{2}$	$\frac{1}{3}+\frac{1}{6}$	120
22.	Lump-fish, . .	4	$\frac{3}{3}$	60

This table shows approximately the rate of breathing of these fishes in similar circumstances. It will be seen that the rate varies from 15 per minute in the Rockling and Blue Wrasse to 120 in the Minnow and Stickleback. It is remarkable that the two specimens of Wrasse should be so different in rate of breathing. On carefully watching a fish at rest, say in a large tank with nothing to disturb it, I have noticed that the slow breathers especially seem to have a considerable amount of control over their respiratory movements. The fish may be seen to breathe hurriedly for an instant or two and then cease breathing, or breathe irregularly for a time. Whether this is voluntary, or whether it is a condition similar to apnœa, I cannot at present say; but it may be affirmed that when there is a deficiency of oxygen in the water the fish breathes hurriedly. There is little doubt considerable variations, as regards rate of breathing, might be found amongst different individuals of the

same species, in different conditions and of different ages, and the figures I have given above are merely approximative, and are what was ascertained in certain specified conditions.

6. The most striking feature of these curves, however, is their diversity of form. When I began the research this result was not expected, and it was with the greatest interest I found that each species seemed to have a form of its own, or, at all events, to present some slight modifications from that of others.

7. In fig. 10, Plate XXVIII., I have given a copy of a portion of a tracing taken from a Gold Carp, with a rapid movement of the cylinder, as indicated by the chronographic tracing. It will be seen that the opening of the gill occupies a shorter time than the closing, and that the opening is almost a uniform movement, whilst during the closing there is a kind of dicrotism or double movement, indicated by the form of the curve. In another tracing, not given in the plate, I took the movement on a cylinder moving with great rapidity, and time was recorded in $\frac{1}{100}$ths of a second, with the following result:—

Time occupied by opening of gill, . . .	$\frac{33}{100}$
Period during which the gill remained open, .	$\frac{15}{100}$
Time occupied by closure of gill, . . .	$\frac{44}{100}$
Period during which the gill remained closed,	$\frac{10}{100}$
Total time of complete respiratory cycle, .	$\frac{102}{100}$

Repetitions of this experiment gave similar results, and although no undue stress need be laid on the figures, they evidently show (1) that the gill (in the Goldfish) opens in a shorter time than it closes, and (2) that there are two pauses in the movements—one when the gill-covers are fully opened, and the other when they are fully closed.

8. But what has just been pointed out with reference to the Golden Carp does not apply to many other fishes. For example, in the Perch (2), the time occupied by the opening is longer than by the closing, the reverse of the Goldfish. The same is seen in the Whiting (11), the Flounder (14), the Dog-fish (16), the John Dory (17), the Rockling (18), the Blue Wrasse (20), and in the Lump-fish (22). It is most marked in the Perch and Whiting. Again, in the Loach (5), the Dace (6), the Minnow (7), the Cod (12), the Saithe (13), the Herring (15), the Common Wrasse (19),

and the Stickleback (21), the periods of opening and closing are about equal.

9. The form of the curves presents many peculiarities. Thus the "dicrotism" (shown by the undulation of the curve) is seen during the *closing* of the gill in the Tench (1), Fresh-water Eel (4), Minnow (5), Gold Carp (9), Herring (15), and during the *opening* in the Whiting (11), Flounder (14), Dog-fish (16), Rockling (18), and Lump-fish (22). On examining the original curves with a magnifying glass, it can be seen that in no instance is the movement either of opening or closing quite regular, and if there be no indication of "dicrotism" in the opening, it will be found in the closing, and *vice versa.* It is interesting to observe the character of the movement in the Pike (3), where the opening curve is convex, indicating an acceleration and diminution of muscular effort, and the closing curve slightly concave. A somewhat similar action is seen in the John Dory (17), but in this case the opening curve is concave. In the Dace (6) I have always found the notch in the apex—that is, at the moment the gill has been closed. The plate fails in giving an adequate notion of the regularity of the curve from this fish, and I am inclined to think it is the "dicrotic" curve seen in the Tench (1) and Gold Carp (9) coming in later than in these fishes. The curve of the Minnow (7) shows a slight "dicrotism" during the closing, and it also is near the apex.

10. By the mechanical arrangements above described, the movements of the gill-covers were amplified ten times, and the same arrangements apply to all the tracings shown in the plate. It will be seen that the amplitude of the movement of the gill-cover shows striking differences. There is evidently no very direct relation between the size of the fish and the amount of movement. Thus a Pike (3), 14 inches in length, and a Whiting (11), 12 inches, do not give movements of much amplitude, not far exceeding those of a small Minnow (7), 2 inches, or a Stickleback (21), 2½ inches. With some fishes I found great difficulty. The amplitude of movement of the gill-covers of the Herring, for example, is so small, and the force so weak, that it was with great difficulty, and after many failures, that I got a fair tracing. On the other hand, the little Minnows move their gill-covers through so great a distance comparatively, and with such force,

as to make it easy to get a record. The movement in the Dog-fish was also troublesome to record, as it had more the character of an undulation than a stroke. From this fish I obtained tracings by placing the "button" of the transmitting tambour (1) over the gill openings, (2) about $\frac{1}{2}$ an inch to the inner side of the openings, and (3) over the lower part of the throat, and in all situations the curve obtained was the same.

11. I have not yet attempted an investigation of the nervous, muscular, and elastic arrangements by which these movements are produced. It is clear, however, that they must differ in many species of fishes, and that they are adapted to the necessities of the organism. Only a very lengthened research can work out the problems of branchial respiration, such as the relations, if any, between the number of branchial processes, the capacity of the branchial chamber, the force and rhythm of the heart, and the mechanism by which the branchial currents are produced.[1]

[1] I have to thank Mr Paton, F.L.S., curator of the Museum, West-End Park, Glasgow, and the Manager of the Aquarium at Rothesay for allowing me the use of fishes in this research. The Directors of the Rothesay Aquarium are anxious to give every facility which their establishment can afford for the prosecution of scientific work.

ON SOME POINTS IN THE ANATOMY OF THE PORPOISE (*PHOCÆNA COMMUNIS*). By GEORGE BOND HOWES, *Demonstrator of Biology in the Royal School of Mines.* (PLATE XXIX.)

I HAD placed at my disposal last summer, through the kindness of Professor Parker, F.R.S., the carcase of a fœtal Porpoise,[1] and while dissecting it some structures have come under my notice, of which I fail to find any account among the many elaborate monographs devoted to cetology.

The specimen was that of a male, evidently nearing the time of its delivery, and measuring (following the curve of the body along the dorsal middle line) 22 inches in length. The integument which covered the anterior part of the head had been removed, but Mr Buckland's description shows that there were two "whiskers" present upon each side of the nose, and that the eyes were open.

Situated in a line with and an inch and a quarter behind the eye was to be found the external auditory aperture, into which a fine bristle could be readily passed. Overhanging this aperture there was a filamentous process of the integument which measured a quarter of an inch in length, its pointed extremity being turned forwards, while behind it became somewhat broadened, fading off into that covering the head.

This structure was perfectly symmetrical upon both sides of the body, and is represented in fig. 1 as seen on the right side, the external auditory aperture being indicated by a dot seen through it. That it represents a rudiment of the pinna of the external ear there can be no doubt, and, so far as my knowledge carries me, no such organ has before been observed among the Cetacea. Wyman, however, in describing the anatomy of Beluga,[2] found the external auditory aperture capable of admit-

[1] By him received from Mr F. Buckland, who has recorded its capture in *Land and Water* for April 26, 1879.

[2] Wyman, "Description of a White Fish or White Whale (*Beluga borealis*)," *Boston Journal of Nat. Hist.* vol. vii.

ting a bristle and "surrounded by a very slight elevation of the integument."

I have, through the kindness of Professor Huxley, examined the auditory aperture of a fœtal Beluga, the specimen being that of a female, measuring 13 inches in length, and hence much younger than the porpoise just described.

The external ear opens, in this creature, a little above and three quarters of an inch behind the eye, by a minute slit-like aperture, somewhat crescentic in shape, and having its concavity turned forwards; there projects out of this aperture a delicate filamentous process, having the same general appearance as that observed in the Porpoise, save that it is more slender and appears to spring from the integument forming the posterior lip of the aperture, rather than altogether behind it. It is represented in fig. 2 as seen on the right side, being relatively longer upon the left. In a second fœtal porpoise, of the same absolute size as this Beluga, I could find no trace of the pinna, the auditory aperture being excessively small and demonstrable only with some difficulty.

The like is true of a young male about two-thirds grown, but in two other specimens, the one an old female (from which the smaller of the two fœtal specimens was taken) and the other a younger female, measuring respectively 5 feet 10 inches and 4 feet 6 inches in length, I have observed the pinna to be present, curiously upon the right side only, neither of them presenting any trace of it upon the left. The latter of these is further interesting (see fig. 2) from the fact that the external auditory aperture of the side bearing the pinna, opens by a somewhat expanded and funnel-shaped mouth, that of the opposite side being quite small.

In both of these the pinna was much smaller than in the fœtal specimen. I have failed to discover aught else than a few fatty connective tissue fibres in two of the pinnæ examined microscopically, as also to observe any such rudiment in fœtal specimens of *Delphinus leucoptus*, two dolphins (? spec.), and *Megaptera*.[1]

In an account of the anatomy of the auditory organ of the

[1] These specimens and that of the young male Porpoise, are in the keeping of the Zool Dept., British Museum.

Cetacea, Professor Owen having described the course of the meatus auditorius externus, states[1] that "its walls are, in the subcutaneous part of its course, strengthened by a few longitudinal cartilages with elastic connections, allowing of slight changes in length and disposition." The excessively tough nature of the "blubber" in this region, together with the delicacy of these structures, offer considerable obstacles to ordinary methods of dissection; but I am satisfied that whatever may be their meaning, some of them at least are direct tubular outgrowths of the cartilaginous meatus, and take an irregular course through the tissue surrounding that tube, ending in some cases in a slightly expanded and flattened extremity.

Describing the respiratory apparatus in the Porpoise, Professor Huxley states[2] that "the epiglottis in front and the arytenoid cartilages behind are prolonged into a tapering tube, dilated at its summit into a knob." Here follows an account of the relations borne by the glottis to the nasal chamber and soft palate, but, so far as the description of the cartilages is concerned, it agrees in the main with all others of the "prolonged" cetacean larynx with which I am acquainted. Dr Watson and Mr Young, however, in a recently published monograph upon the anatomy of the Northern Beluga (*Beluga catodon*),[3] have discussed fully the morphology of the larynx and its muscles; and, concerning the arytenoid cartilages, they state that "the posterior border of each cartilage is straight as far down as the articular surface, below which it curves outwards, downwards, and then inwards towards the interior of the larynx, where it recurves upon itself. Situated upon this border is a well-defined tubercle, marked on its internal aspect by an articular surface, by means of which the arytenoid articulates with the cricoid. From the tubercle a ridge extends upwards, the lower part of which affords attachment by means of a fibrous membrane to the basal portion of the epiglottic cartilage. The cartilages of Santorini and Wrisberg are entirely absent.

It is chiefly to this "tubercle" that I wish to draw attention, the account quoted leaves one in doubt as to whether it is a

[1] Owen, *Anat. and Physiology of the Vertebrata*, vol. iii. p. 224.

[2] *Anat. of Verteb. Animals*, p. 409.

[3] *Trans. Royal Soc. of Edinburgh*, vol. xxix. p. 414.

distinct nodule or not, while the accompanying figure[1] rather favours the supposition that it is. However that may be, the cartilage regarded as arytenoid in the Porpoise is made up of two distinct masses. The upper one (figs. 4 and 5 A) is a thin lamina, prolonged upwards a little higher than the epiglottis, while below it is produced downwardly and anteriorly into a process which approaches slightly the interior of the larynx. At this point it is continuous with a mass of cartilage, *a*, which is broken up into a number of bits, and ends anteriorly in a freely projecting point, *b*, the whole being buried up in the thickened mucous membrane lining this region. From this same point there goes off externally a fibro-cartilaginous band of considerable thickness, *c*, which is directly continuous with the basal portion of the epiglottic cartilage, E, and appears to answer to the fibrous membrane described in Beluga. The lower one (figs. 4 and 5 A′) is throughout life firmly united by a fibrous interval to those just described, the separation between them being most marked in the young state. It presents internally a smooth, flat surface, while externally it slopes slightly backwards and outwards, and bears a thickened, oval prominence, which overhangs the anterior margin of the cricoid and serves as a point of attachment for the muscles of the arytenoid series.[2] It also furnishes, on its inner side, the oblique inwardly directed articulation for the cricoid.

If we compare these cartilages with those of the dog's larynx, we see that they have essentially the same arrangement. Articulating with the cricoid is a massive cartilage (figs. 6 and 7 A′), having all the characters of that described in the Porpoise, and undoubtedly a true arytenoid. United with it above is a fibro-cartilaginous mass, which upon removal of its denser fibrous covering is seen to consist of two portions and sends off two cornua,—an anterior one, A, which lies beneath and produces a conspicuous elevation of the mucous membrane stretching between the arytenoid and the epiglottis, and a posterior one, *c*, which is directed backwards over the hinder edge of the arytenoid, while anteriorly this mass sends a prolongation into the

[1] *Op. cit.* pl. viii. fig. 6.

[2] For an account of the muscles of the Porpoise, see Stannius, "Beschreib. der Musk. des Tummlers, *Müller's Archiv. f. Anat.* 1849.

false vocal cord, which appears to be homologous with that portion marked *b* in the Porpoise.

These cornua have exactly the relations of, and no doubt are homologous with, the cartilages of Wrisberg and Santorini, and if so, the upper portion of the so-called arytenoid of the Porpoise, which is prolonged into the nasal passage, must represent an elongated cuneiform cartilage—cartilage of Wrisberg—the Santorinian element being absent.[1] It is interesting to note here that Professor Huxley has recently pointed out that by carefully dissecting a dog, disturbing as little as possible the head and neck, the larynx may frequently be found lying within the nasal passage, and not in the cavity of the mouth; this being so, the disposition of the surrounding parts shows what a comparatively slight amount of modification would be necessary in order to convert the canine larynx into that of the cetacean.[2]

The hyoid bone of the adult Porpoise presents us with a flattened basal plate (fig. 10, *b. h.*), with which are ankylosed behind the enormous posterior cornua, *th. h.*, while in front articulate the anterior cornua, each consisting of a well-ossified cerato and stylohyal respectively, and becoming united above with a small bony tympano-hyal.

While examining the hyoid bone of the larger fœtal specimen, my attention was drawn to the presence of a nodule of cartilage, which lay along the inner edge of the posterior cornu (fig. 9, *br.* 2). This structure is somewhat lozenge-shaped and flattened from above downwards; anteriorly it presents a rounded margin,

[1] The anatomy of the cetacean larynx and certain other parts will be found fully discussed, together with an excellent bibliography, in Messrs Watson and Young's monograph.

[2] In the Hedgehog the larynx forms a complete tube, closed behind for its entire course, and situated within the nasal chamber. Physiologically, therefore, this is a cetacean larynx, but, morphologically, it differs somewhat from such. In the former, the creature has a suppressed cervical region, very little motion is allowed of the head upon the trunk, and hence the stiff and unyielding laryngeal cartilages are "buttoned" into the nasal chamber. In the latter, considerable flexibility of the cervical region is necessary for the ordinary movements of the animal, and to meet this, the cartilages themselves remain flexible, and are not prolonged upwards for any distance as in the Porpoise; the soft palate growing backwards forms, together with the roof and sides of the nasal passage posteriorly, a circular lip which embraces them firmly behind, fitting into a depression at the back of the arytenoids, while at the sides and in front its embrace is less binding, and allows free play for the epiglottis.

while posteriorly it continues the line described by the backward curve of the inner edge of the cornu, upon the bony substance of which it exhibits a strong tendency to graft itself. Upon careful examination it was seen to be imbedded in some strong elastic fibres, which ran from the inner and ventral edge of the posterior cornu to the hinder border of the basi-hyal (figs. 8 to 10, *lg.*). Careful search has revealed the constant presence of this nodule; it is largest at the time of birth, and is represented in the adult by a mere shred of cartilage (fig. 10, *br.* 2).

The only account, among the mammalia, with which I am acquainted, of any structure of a nature at all approaching this, is one of the Sea-lion (*Otaria jubata*), where Dr Murie[1] has described and figured the cartilago-triticea with its usual connections, and in addition, "a figure of eight nodule, lying in the thyro-hyoid ligament."

This nodule, which may or may not belong to the laryngeal category, certainly is not present in the Porpoise; but it seems impossible to regard the one which I have described as other than a remnant of one of the post-oral visceral arches, such as are now known, upon an abundant supply of evidence brought forward by Professors Huxley, Parker, and others, to exist in the Urodele amphibia. Professor Parker has further shown that[2] in the Pig the posterior cornu of the hyoid represents the lateral elements of the first branchial arch of a fish; this being so, it follows by analogy that the aforementioned cartilage and its investing fibres must represent the remains of a second arch of the same series.

Viewed from this standpoint, the Porpoise's hyoid compares favourably with that of other mammals.

Take, for example, that of the Rabbit: we find that in the former the whole structure has become flattened, in order to form, along with the expanded alæ of the thyroid cartilage, a solid support for the floor of the mouth, the posterior cornua hence being compressed from above downwards, while in the latter (fig. 11) the opposite obtains, they being compressed from side to side.

[1] Murie, On the Anatomy of the Sea-lion, *Trans. Zool. Soc.* 1870.
[2] On the Development of the Pig's skull, *Phil. Trans.* 1874.

It follows that the internal margin of the posterior cornu of the former must be homologous with the anterior one of that of the latter, in which, too, the cornu is tied down to a backwardly directed projection of the body of the hyoid by a strong band of elastic fibres (fig. 11, *lg.*), and if the above view is correct, these must represent those observed in the Porpoise.

The cartilaginous nodule enlarges rapidly during the latter half of intra-uterine life (see figs. 8, 9), attains its maximum at birth, at which period the hyoid is still largely cartilaginous, and then fades away, as ossification becomes more dense and as ankylosis sets in. Still, it can hardly be regarded as of physiological importance, but rather as a remnant which the Porpoise alone may retain among mammals, or, it may be, that further investigation will reveal in them the more universal presence of this characteristically amphibian structure.

The occurrence, in so old and specialised a group as the Cetacea, of a rudiment of the pinna of the external ear, presents us with a case of "reversion" of considerable interest; and its occasional appearance upon one side only is curious, in that the skull of some of the species is known to want symmetry.

It may be worth noting that in the smaller of the two females dissected, the ductus arteriosus was open, allowing a fine stream of injection to pass: it was found by Professor Turner to be closed in a young Pilot Whale 8 feet long.[1]

Explanation of Plate XXIX.

Fig. 1. *The rudimentary Pinna, Phocæna,* fœtal male.
Fig. 2. *The rudimentary Pinna, Phocæna,* adult female.
Fig. 3. *The rudimentary Pinna, Beluga,* fœtal female.
Each of the right side and slightly enlarged.

The Laryngeal Cartilages.

Fig. 4. *Phocæna,* fœtal male, from within, in section.
Fig. 5. *The same,* right side from without. (The epiglottis thrown forwards.)
Fig. 6. *Canis,* from within, in section.

[1] *Journ. of Anat. and Physiology,* vol. ii. p. 70.

Fig. 7. *Canis*, right side from without.

A, the cuneiform cartilage; A′, the artenoid; C, the cricoid; E, the epiglottis; T, the thyroid; *c*, the cornicula of the larynx.

(All drawn to natural size.)

The Hyoid Bone.

Fig. 8. *Phocœna*, fœtal female, young.

Fig. 9. *Phocœna*, fœtal male, near delivery.

Fig. 10. *Phocœna*, adult female.

c. hy. The anterior cornu—cerato-hyal.

th. hy. (Br. 1.) The posterior cornu—thyro-hyal.

b. hy. The basi-hyal.

lg. Ligamentous fibres, in which are embedded

Br. 2. Remains of a second branchial arch.

(All drawn to natural size.)

Fig. 11. *Lepus cuniculus* (adult).

a.c. The anterior cornu.

p.c. The posterior cornu.

(Other letters as above. Twice natural size.)

TWO MASKS AND A SKULL FROM ISLANDS NEAR NEW GUINEA—A CONTRIBUTION TO ANTHROPOLOGY. By Professor TURNER, M.B., F.R.S.[1] (PLATE XXX.)

THE masks and cranium which form the subject of the present communication were presented to the Anatomical Museum of the University of Edinburgh by one of my pupils, Mr J. Wharton Cox, of Sydney, New South Wales. They were obtained by his father, Dr Cox of Sydney, the well-known and accomplished Australian naturalist. In sending these specimens to his son Dr Cox wrote as follows:—

"I send two very curious masks made by cutting off the forehead and face of a dead native, and preserving them. The frontal bone and part of the upper and lower jaw are intact. They are really very curious, and of value. In the box also is a mud figure from New Ireland or New Britain, where also the masks are from, and also the face of a god in wood."

New Britain and New Ireland are two large islands situated in proximity to each other, and lying to the north and east of New Guinea.

Both masks were apparently from the heads of men, and in both the upper border of the mask was formed by the frontal bone up to the coronal suture.

In the larger mask a fringe of frizzly black hair, arranged in locks about 1 inch long, bounded the coronal border of the frontal bone. It evidently formed a part of the hairy scalp. The forehead and face were stained with bands and stripes of black, red, and white pigments. At the first sight it seemed as if the pigments had been smeared on the dried and hardened integument, but on scratching the surface with a knife it felt hard and gritty. A portion was then removed and heated on platinum foil, when it soon ignited and burnt with a yellow flame, leaving a proportion of grey ash. Another portion, heated in a glass tube, gave off a dense vapour, which condensed in the cooler part of the tube into a thick yellow liquid, the residue blackening and

[1] Communicated in abstract to the Royal Society of Edinburgh, May 17, 1880.

leaving a grey ash. It seemed probable, therefore, that the forehead and facial bones had been covered with a mixture of an earthy material and resinous substance, which had been applied in a plastic condition so as to be modelled into the form of a face, and then allowed to dry. The pigments employed were apparently a red ferruginous earth, a white lime probably obtained from burnt coral, and a black substance, probably the black oxide of manganese. A broad red stripe was smeared across the forehead immediately in front of the hair, which it had partially coloured. Below this was a transverse white band; still lower down in succession a much broader transverse black band, a red band, and a white band. The eyebrows were sharply modelled, and they were made to meet in a mesial elevation immediately above the root of the nose. The eyelids were represented, and separated from each other at the palpebral fissure, but the orbits were quite empty. The nose was moderately prominent, compressed at the sides, and its bridge formed an almost straight crest, but the alæ had, unfortunately, been broken off. The cavity of the nose was occupied with a hard earthy material. The lips were carefully modelled, but not especially thick and protuberant, and the lower lip projected a little beyond the upper. The mouth was partially open, its transverse diameter at the orifice was 2·2 inches; immediately within the lips indications of teeth were seen. Immediately behind each cheek a longitudinal ridge had been modelled, which was marked by transverse notches to represent the whiskers; these ridges were joined together below at the chin, where they were elongated downwards so as to simulate a stunted beard. The eyelids were blackened on the surface, but reddened along the palpebral fissure. The cheeks, chin, and nose were smeared with red, white, and black stripes. The edges of the lips were reddened, and a broad red band was carried down each whisker to meet below the chin.

The mask was hollowed behind by the removal of the frontal part of the brain, the contents of the orbits, the orbital plates of the frontal bones, the ethmoid, and sphenoid; and the small part of the nasal fossæ remaining was filled up with a hard earthy material. A loop of string had been attached to each side of the mask on a level with the eyebrows, by which it had been without doubt suspended to a peg in the hut of its owner. Below this

loop, and almost on a level with the back of the mouth, a transverse bar of wood was firmly attached to each side of the mask, being imbedded at its two ends in the hardened material which had been used in the modelling. This cross bar formed a handle by which the mask could be held. The surface of the wood was, however, seen to be abraded, as if by the action of the teeth, so that it is not unlikely that it had been held in the mouth of the person using the prepared face for a mask, who could at the same time have seen distinctly through the eye clefts, and breathed freely through the open mouth.

The extreme length of the mask from the hair to the lower edge of the artificial beard was 10 inches, its greatest width at the attachment of the loop of string was 6 inches.

The smaller mask also consisted of the frontal and facial bones, but differed in many particulars from that just described. The fringe of hair along the coronal border was absent, and the ascending plate of the frontal bone was not covered with any composition, although remains of a white pigment were to be seen on it, as if it had originally been marked with a pattern of some kind. A red band traversed each supra-orbital ridge, and a projecting pair of eyebrows had been modelled immediately below this band in a hardened material. The artificially prepared eyelids were widely open, and their margins coloured with a red pigment. Instead of the orbits being empty they were occupied by a similar hardened material to the eyebrows, and in the centre of this substance an artificial eye formed of the operculum of a mollusc (*Turbo operculum*) had been introduced. Each operculum was dark green, shading almost into black in the centre of its exposed surface, and its coloured centre was surrounded by a white zone; both in shape and colouring it closely resembled the iris, pupil and surrounding sclerotic coat of the eye. The nose was moulded into a low aquiline form, it was swollen out at the sides, and the bridge was sharp; the nostrils were open and directed downwards, their alæ were coloured red, but the sides and bridge of the nose were white. A thread had been introduced through the ala of each nostril and a bead strung on it. The cheeks, chin, and lips, which had all been modelled in a material similar to that used in the larger mask, were striped with black, red, and white pigments, and a row of white spots had been painted on the

chin above the beard and in front of the whisker. The mouth was open, the lower lip projected a little beyond the upper, the transverse diameter of the lip fissure was 2·1 inches, and the lips were not specially thick and protuberant. Placed in its cavity, and projecting slightly between the lips, was an artificial tongue formed of bright red cloth, folded on a semilunar frame of wood. Attached to the sides of the face was a pair of whiskers, which met below the chin in a beard. They were formed of a whitish vegetable fibre, the threads of which were from ¾ to 1½ inch long. The arrangement of the beard and whiskers, combined with the painted face and the very natural appearance of the eyes, give quite a pantaloon-like aspect to the mask.

The brain had been removed from the frontal part of the skull, but the ethmoid and sphenoid bones were in position, and the nasal cavities were filled with a hard substance, similar apparently to that used in modelling the face. The lower jaw was almost entire, only the condyles being wanting. There was no loop, or string, or cross-bar attached to this specimen, which had evidently had a different purpose from the one first described; for from the orbits and mouth being filled, and the sphenoid bone in position, it could not have been worn as a mask. Probably, from its elaborate decoration, it was used as an ornament, or it may have been as an object of worship.

The wooden god referred to by Dr Cox in his letter was carved out of a single piece of wood. It stood 5¾ inches high, and was carved to represent the head and upper limbs. The face was greatly prolonged forwards to the end of the nose and mouth, but with a vertical forehead; it combined the facial characters of both man and the pig. The long axis of the nose was almost horizontal, and terminated with truncated nostrils directed forwards. The mouth was below and slightly in front of the end of the nose, with the lips asunder and the tip of the tongue protruding. The eyes were each represented by an elliptical plate of mother-of-pearl. The outer edge of the plate was serrated, and a hole, to simulate the pupil, was cut out of the centre of each plate. The ears were vertically elongated, and the lobules disproportionately large. The upper arms were placed vertically immediately below the head. The forearms were directed horizontally forwards, and each terminated in a hand, on the

top of which the chin rested. The face and limbs were stained black, but the tongue and lips were reddened, and a red band was painted transversely immediately above the black forehead.

The "mud figure," also referred to by Dr Cox, consisted of a face, nearly 6 inches long and 4½ inches wide. The features were in low relief, and not very artistically modelled. The nose had, however, the low aquiline contour similar to that present in the second of the two masks already described. A simple incisor tooth from a small mammal had been inserted into the facial surface of the ala of each nostril. The eyes and mouth were both represented as open. The face had been modelled in clay or some tenacious earth, which had been subsequently hardened either by fire or by drying in the sun, and the surface was painted a bright red. The material had been modelled on a frame of wood, a portion of which projected below the chin, so that the native artist had pursued a mode of work not unlike that followed by a sculptor in modelling a bust or large figure.

M. Quoy, the naturalist on board the "Astrolabe" (*Histoire du Voyage*, by M. D'Urville, vol. iv. p. 736), in describing the natives of New Ireland, states that they have a wide face, small eyes (a little oblique), and a broad, flat nose. They pierce themselves above the nostrils with one or two holes, into which they attach the small canine teeth of the pig; and as these diverge from each other like little horns, they give a singular appearance to the physiognomy.

Two of these natives from Carteret Harbour, with their curious nasal appendages, are figured in plate 99, vol. i. of the Atlas of M. D'Urville's *Histoire du Voyage*.

In modelling the face of the "mud figure," the native artist had introduced similar nasal appendages to those worn by the people of his tribe, and a similar method of ornamentation, though with different materials, had been employed in the smaller of the two masks.

Warrior Island, from which the skull was obtained, is on the north side of Torres Straits, immediately to the south of the great Warrior Reef. The skull is that of a man, and Mr Cox tells me that it was obtained from the widow in exchange for a few yards of calico and some beads.

It had been completely divested of all the hair and flesh, and had then been ornamented, but in a much less elaborate way than the masks just described. The skull was perfect, and included the lower jaw. A broad band of red pigment had been smeared across the frontal bone immediately above the glabella and supraorbital ridges. Slightly projecting artificial eyebrows were modelled along the lower margin of those ridges in a black material. The orbits were filled up with a similar hardened material, painted red on its surface, and in the centre of this red surface a thin lozenge-shaped plate of mother-of-pearl was fixed. The long axis of this lozenge, 1⅜ inch, was placed transversely across the orbit, the short axis measured only half-an-inch. The upper and lower jaws were connected together by string of native manufacture, which had been passed through the nasal cavity and under the symphysis menti; that part which lay in the face was coloured red. The condyle of the lower jaw was tied by string to the root of the zygoma on each side. Attached to the left zygomatic arch was a piece of plaited string 8 inches long, which had probably been used for suspending the skull. Numbers of small limpet-like shells were threaded to the string and ornamented it.

The most curious feature in this prepared skull was the artificial nose with which it was provided. A plug of hard wood, 3¼ inches long, had been inserted into the nasal cavity, the mesial septum having mostly been broken away in order that the plug might be accommodated. The end which projected beyond the anterior nasal aperture was 1¼ inch long; it was painted red, and had two elongated nostrils, separated from each other by a mesial septum carved in it. This artificial nose was pointed at its tip, and projected, almost at a right angle, to the nasal bones.

Some of the incisor and canine teeth were absent, but they had obviously dropped out after death, for the sockets were unabsorbed. The teeth were not artificially deformed, but were stained in patches of a reddish-yellow tint.

The skull was that of a man in the prime of life. The sutures were distinct, though it is not improbable, from their appearance, that some amount of synostosis of the inner table had taken place. It was markedly brachycephalic, the greatest width

being in the parietal region, below the temporal ridge, which was distinctly double.[1] In its antero-posterior contour the vault of the cranium ascended in a gentle curve to the vertex and then rapidly sloped downwards from the obelion, so as to present a well-marked parieto-occipital flattening, and as the squama of the occipital bone, between the inion and lambda, was almost flat, one was led to believe that some pressure had been applied during infancy to the back of the head. As a consequence the glabello-iniac and glabello-occipital diameters were almost equal. No trace of artificial flattening was seen in the frontal region. The glabella and supraorbital ridges were not prominent. The fronto-nasal depression was slight. The bridge of the nose was not flattened, but formed a fairly marked projection. Both the upper and lower jaws were massive, and the palate had a depth of 14 mm. opposite the second molar tooth. The inferior anterior angle of the parietal had a very narrow articulation with the sphenoid at the right pterion, and on the left side a small Wormian bone separated the sphenoid and parietal. Small Wormian bones were present in the lambdoidal suture. The dimensions of the skull are given in the following measurements, expressed in millimetres :—

Glabello-occipital length, ...	175·0
Glabello-iniac length, ...	173·0
Extreme breadth, ...	154·0

The cephalic index was therefore 88, so that the skull is of a pronounced brachycephalic type. It is possible that the artificial pressure to which the back of the head had apparently been subjected in infancy may have increased the brachycephalic character. The basi-bregmatic height was 137·0 :[2] horizontal circumference, 515 : cubic capacity, 1650 cubic centimetres : longitudinal arc, 374 mm. ; frontal, 130 ; parietal, 135 ; occipital, 109 : stephanic diameter, 122 ; minimum frontal, 103 ; asterionic, 120 : vertical transverse girth between supra-auricular points, 325. The antero-posterior diameter of the foramen magnum

[1] See On the Double Character of the Temporal Ridge, Memoirs by Professor Hyrtl and Dr Jhering. Also Professor Cleland's paper "On a Sulu Skull" in *Journal of Anatomy and Physiology*, vol. xi. p. 663.

[2] This and most of the other measurements have been taken as recommended by Professor Paul Broca, whose descriptive terms have also been largely adopted.

was 35 mm.; its width 28. The auditory-alveolar radius was 110;—fronto-nasal, 98;—bregmatic, 127;—parietal, 133;—occipital, 95 mm. The altitudinal index is 78.

The transverse diameter of the face between the zygomata was 140. The cranium is not phœnozygous. The height of the face from the ophryon to the alveolar point was 90, and to the chin 141. The facial index was 64. The nasal length 47, its breadth 24, giving a nasal index of 51, which places it in the mesorhine division of Broca. The orbital dimensions and index, owing to the orbits being filled up, cannot be definitely ascertained.

The basi-nasal length was 105, the basi-alveolar 107. The alveolar index is 101·9. The face is, therefore, mesognathous.

The lower jaw measured between its angles 103, from angle to point of chin 102, height at symphysis 31, height at coronoid 75 mm. The skull is brachycephalic, megacephalic, mesorhine, and mesognathous.

Warrior Island was visited by H.M.S. "Basilisk" in 1871, and Captain Moresby has given an interesting account of the place and people.[1] He states that, though not more than two miles in circumference, it is the home of one of the most powerful tribes in Torres Straits. The natives build formidable war canoes, 50 to 60 feet long, and the powerful men that man them are armed with six-foot bows, which send the poisoned arrows true to the mark at 80 yards. They cultivate the soil for yams, taro, and sweet potatoes. In former years they attacked a man-of-war when becalmed near the island, and were with difficulty driven off. They have been an aggressive people.

Warrior Island (l'île Toud) had been previously visited in June 1840[2] by the French ships "Astrolabe" and "Zélée," under the command of M. D'Urville. M. Jacquinot, who wrote the account of the zoology of the voyage, states[3] that they were able to examine on this island a number of natives, some of whom had the face elongated, the nose aquiline, the lips moderately large, and the forehead fairly developed. In the greater number a flattening of the back of the head, sufficiently well marked, was observed.

[1] *Discoveries in New Guinea*, p. 27, London, 1876.
[2] *Voyage au Pole Sud. Histoire*, vol. ix. p. 220.
[3] *Ibid.* Zoologie, vols. i. ii. p. 370.

Their hair, instead of forming the enormous *coiffures* seen in other Papuans, was arranged in small ringlets pendulous on all sides. They were more industrious and more enterprising than the Australians. In the Natural History Museum in Paris is the cast of the head of a man, one of these islanders, taken by M. Dumoutier, which shows in a very characteristic way the flattened form of the parieto-occipital region; the nose also is aquiline, but not very prominent.

The flattening of the back of the head referred to by M. Jacquinot is in conformity with the character of the skull described in this communication, and points to a practice more or less general of employing artificial pressure in infancy to the back of the head.

If the skull now before us is to be taken as a fair sample of an adult male of these Islanders, they are obviously a people with well developed crania, possessing a large brain cavity, so as to accord with the character of a vigorous race, such as they are described to be by Captain Moresby. In their strongly pronounced brachycephalic form, and large internal capacity, they differ in the most decided manner from the dolicocephalic Australians to their immediate south, whose cephalic index, deduced from the measurement of 100 crania, averages not more than 72,[1] whilst the average cubic capacity of the male Australian skull, deduced from 26 specimens, is only 1285 cubic centimetres—*i.e.*, distinctly microcephalic. The Australians have also a prognathous upper jaw and a platyrhine nasal index.

This skull differs also from those of their Papuan neighbours to the north and north-east, not only in its much larger capacity, but in the relative proportions of length and breadth. The mean cubic capacity of the fourteen out of fifteen Papuan crania collected by Dr Comrie on the south-east coast of New Guinea is stated[2] to be 75 cubic inches; the highest, a male from the Teste Island, being 84 cubic inches, the lowest, also said to be males, 64 and 65 cubic inches. Their average cephalic index was 73·5, the highest indices in the three specimens being 80 and 81,

[1] Flower on "The Native Races of the Pacific Ocean," *Proc. Royal Institution of Great Britain*, May 31, 1878.

[2] *Journal Anthrop. Inst.* vol. v. p. 103.

the lowest in one specimen being 68. In his description of these crania Dr Comrie states that the general type of skull was that of an extended, but narrow and compressed form, the forehead small and low, the occiput flattened, and the zygomatic space not extensive. In two specimens, however, the occipital protuberance was strongly déveloped.

Professor Flower has also recorded measurements of thirteen of the above crania,[1] now in the museum of the Royal College of Surgeons of England, the average cephalic index of which is 73, and their cubic capacity 1255 cubic centimetres. These Papuans are, therefore, a dolicocephalic people, although the cephalic index of an individual skull may assume mesaticephalic, or even brachycephalic proportions. They are microcephalic, have a mesorhine nasal index, and are as a rule prognathous.

The two remaining crania were presented by Dr Comrie to the Anatomical Museum of the University of Edinburgh. The one, from Possession Bay, is 176 mm. long and 120 broad, with a cephalic index of 68. This skull is markedly dolicocephalic, although the occipital squama does not bulge backwards, so that the long diameter of the skull is in the glabello-iniac line. There is, however, nothing in the appearance of the skull to lead one to think that artificial flattening had been practised, as the parietal bone did not pass almost vertically downwards from the obelion. The other, from D'Entrecasteaux Island, has a glabello-iniac diameter of 161 mm., but its extreme length is 167 mm., its breadth is 134 mm., and it has a cephalic index of 80, so that it falls within the numerical brachycephalic index. Its parieto-occipital region, though not so vertical as in the Warrior Island skull, appears as if it might have been artificially flattened, although, as the measurements show, the occipital point projects considerably further back than the inion.

On the assumption that this cranium from Warrior Island is a fair example of the people, and not exceptional in its proportions, these islanders differ also materially from their neighbours on Darnley Island (Erroob), which is situated nearly 50 miles to the eastward. From an analysis of the measurements of the crania of four adult male Darnley Islanders recorded by Professor

[1] *Osteological Catalogue*, part 1, 1879.

Flower,[1] the average cephalic index is 72·6, the average cranial capacity 1323, although one of the four crania was as high as 1510 cubic centimetres, so that they are, as a rule, microcephalic; they have a mesorhine nasal index, and are distinctly prognathic. The Warrior Islanders, therefore, have to the north, south, and east dolicocephalic races, with prognathic upper jaws and microcephalic brain cavities, whilst this skull is brachycephalic, megacephalic, and mesognathous.

If we turn to the west, however, we find a people, the Malays, occupying either exclusively, or mixed with other races, various of the islands of the great Malayo-Polynesian archipelago. This people is brachycephalic, mesognathous, and mesorhine, whilst their average brain capacity is mesocephalic. The skull of the Warrior Islander shows, therefore, a strong affinity to the Malay type, and it is not unlikely that these islanders may have a large admixture of Malay blood.

Several crania were procured from Warrior Island by M. D'Urville, and are preserved in the galleries of the Museum in Paris. They have been examined by MM. de Quatrefages and Hamy,[2] who state that they consist of two sets; the one, war-trophies, which had been suspended in the huts, and which had perhaps belonged to the people of New Guinea; the others, obtained from the burial-places, and belonging, therefore, either to the race of people at present inhabiting the island, or to a preceding race.

One of the latter set, an adult female, is figured by these authors (fig. 220, 221). It exhibits in the occipito-parietal region, a flattening closely comparable with that present in my specimen. The frontal region approaches more to the vertical than in my specimen, but this is without doubt a sexual character. The nasal bones also are less prominent than in my male skull. In its dimensions the skull in the Paris Museum is, as is to be expected, from the sex, smaller than in my specimen. The capacity is 1270 cub. cent. The maximum antero-posterior diameter is 159 mm.; the maximum transverse 137; the vertical basi-bregmatic 130; the cephalic index is 86·16, almost equal, therefore, to that of my male skull. The horizontal

[1] *Osteological Catalogue*, p. 221.

[2] *Crania Ethnica*, p. 207, 5th part, 1876–77.

circumference is 469 mm. The orbital index is 89·74; nasal index 52·04; facial index 67·46. The skull is brachycephalic, microcephalic, mesorhine, and verging on megaseme in the proportions of the orbit. MM. de Quatrefages and Hamy also give two figures of a male skull from this island in one of their lithographic plates. Unfortunately, there is some confusion between the locality, as specified on the plate itself, and that in the *Explication des Planches.* If the latter, however, is to be taken as correct, then the skull (figs. 1 and 2, plate xix.) is from this island. It exhibits well marked parieto-occipital flattening, and has a strong resemblance, not only in this, but in other particulars, to my male skull. As these figures are drawn half the size of nature, the length and breadth measured on the plate are respectively 178 and 156 mm., giving a cephalic index of 87·6.

We may now proceed to inquire what other evidence has been recorded of the presence of brachycephalic people, either in New Guinea or the adjacent islands. MM. Quoy and Gaimard visited, during the voyage of the "Uranie," the islands of Rawak and Waigiou, situated off the extreme west of New Guinea, and have given an account of the people.[1] From their description the crania are short, broad, and high, and they state that their heads are flattened both anteriorly and posteriorly, and in the plate accompanying this description, where two skulls of natives of Rawak are figured, both crania are seen to have well-marked parieto-occipital flattening, and although no measurements are given, they are obviously brachycephalic. MM. de Quatrefages and Hamy have described, in more detail,[2] the crania collected in Rawak and in the adjacent islet of Boni. In one skull the cephalic index was 88, and the average of five skulls was 86, so that their brachycephalic character is unquestionable, whilst the parieto-occipital flattening is strongly marked. The crania observed at Waigiou by the naturalists of the "Coquille" are described as remarkable for a considerable posterior flattening, and, from measurements given by M. Garnot, the cephalic index is given as 81·8.

[1] *Annales des Sciences Naturalles*, vol. vii. p. 27, plate iii. 1826. The figures of one of these skulls are reproduced by von Baer in *Crania selecta*, plate iii. figs. 4, 5.

[2] *Crania Ethnica*, p. 210.

In 1856, Professor Retzius stated[1] that the museum of the Caroline Institute of Stockholm had received from Dr Wise of Edinburgh three crania of brachycephalic Papuans, which had a striking resemblance to each other, and to the crania described by MM. Quoy and Gaimard. MM. de Quatrefages and Hamy have pointed out[2] that the crania collected by Wise were of the tribe of Karons, a people occupying a chain of mountains, originally known as Arfak, in the north-west part of New Guinea, parallel to the north coast and adjacent to Port Dorei. A description of these crania has been given by MM. de Quatrefages and Hamy, one of whom visited Stockholm for the purpose of studying them. Two of these three crania are not flattened in the parieto-occipital region, one of which has a cephalic index of 78·8, the other of 78·3. The third specimen has, however, a distinct parieto-occipital flattening, and is obviously brachycephalic. Its antero-posterio maximum, the same as the glabello iniac, is 174 mm., the transverse maximum is 146, and the cephalic index is consequently 83·9.

Sandifort has also described[3] a brachycephalic Papuan cranium with a cephalic index of 85, and one with a cephalic index of 83 is in the collection (No. 1401) of Dr Barnard Davis,[4] but the exact localities from which these skulls were procured does not seem to have been ascertained.

From the examination of the living islanders, made by M. Jacquinot, from the casts of the head taken by M. Dumoutier, and from the examination of the several crania recorded by MM. de Quatrefages, Hamy, and myself, there can, I think, be little doubt that the practice of artificially flattening the back of the head prevails to a considerable extent amongst individuals, and, it may be, also tribes of the natives of New Guinea and the adjacent islets, as far apart as Waigiou and Rawak on the west, Warrior Island on the south, and apparently D'Entrecasteaux Island on the east. At the same time there can be no doubt that this practice does not prevail generally in all the tribes of people, as the region of New Guinea has already supplied our

[1] *Forhand ved de Skandin, Naturforsk*, Christiania, July 1856 ; and *Ethnologische Schriften*, Leipzig, 1864.

[2] *Crania Ethnica*, p. 201.

[3] *Tabulæ craniorum.*

[4] *Thesaurus craniorum* p. 305.

museums with many crania of markedly dolicocephalic proportions, in which there is no evidence of an artificial parieto-occipital flattening.

Brachycephalic, mesaticephalic, and dolicocephalic crania have now been obtained from the tribes of people occupying various districts on the coast line. Thus, whilst the observations of MM. Quoy and Gaimard, and of M. Garnot, point to a people with brachycephalic crania, occupying the island of Waigiou, Dr Barnard Davis has in his collection a skull from the same island, with a cephalic index of 77. Again, whilst a brachycephalic people have been found in Warrior Island, the natives of the not distant Darnley Island are dolicocephalic.

But even amongst the mountaineers of Arfak there appears, so far as the scanty material put on record enables us to form an opinion, to be a diversity in the proportions of the cranium; for whilst the skulls of the Karons measured by de Quatrefages and Hamy are either distinctly brachycephalic, or verging on it, a skull measured by Dr Barnard Davis from the same locality (No. 686) has a cephalic index of only 74.

It would appear, therefore, that the people of New Guinea and many of the adjacent islands exhibit considerable differences in the proportions of their crania, some which have been measured having as low an index as 68, whilst others mount as high as 86 and 88. These differences point to an admixture of different races in these islands.

It is, however, to be observed that the skulls possessing high cephalic indices have been also characterised by distinct parieto-occipital flattening, and the influence which artificial pressure, applied to the back of the head during infancy, may exercise, either in producing brachycephalic proportions or in increasing them, is a factor which should not be left out of consideration.

It would be out of place on this occasion to enter into the consideration of the custom of mummifying the dead, as practised by the ancient Egyptians and the Guanches, or ancient inhabitants of Teneriffe. But I may here refer to the very interesting communication made last year by Professor Flower to the Anthropological Institute,[1] in which he described and

[1] *Journal Anthrop. Inst.* vol. viii. p. 389, 1879.

figured the mode of preserving the entire mummified dead body of a man, a native of Darnley Island, Torres Straits, as well as the mummified body of a male Australian, from the neighbourhood of Adelaide.

The practice of decorating and preserving merely the crania or the heads of the dead prevails very extensively amongst the aboriginal inhabitants of the Malayo-Polynesian archipelago, and many collections of crania contain illustrative specimens. Prepared skulls of Dayaks from Borneo are in the collections of the late Professor Vrolik, Dr Morton, Dr Barnard Davis, and in the Museum of the Royal College of Surgeons of England.[1] Some of these are painted and ornamented with tinfoil, and with patterns carved into the bone, whilst the nose and orbits are filled up, and cowrie shells introduced into the latter to simulate eyes. Dried heads of New Zealanders, prepared by breaking away the base of the skull, extracting the brain and its membranes, and then drying the face with its tattoed integument and hair, are in Drs Morton's and Barnard Davis's collections, and in the museums of the University and the Royal College of Surgeons of Edinburgh. The prepared heads of some Solomon Islanders, decorated with pieces of mother-of-pearl, are in the collection of the Royal College of Surgeons of England, and that formed by Professor Allen Thomson. Decorated skulls or heads of Papuans, from New Guinea and from Darnley Island, collected during the voyages of H.M. ships "Fly" and "Rattlesnake," are in the Museum of the Royal College of Surgeons of England. Those from Darnley Island have the integuments of the face dried and painted red, and with artificial eyes of mother-of-pearl inserted into the orbits; whilst those from the south coast of New Guinea were

> "Very curiously ornamented with a wooden projection inserted into the nose, black protruding lumps of gum, like short horns, in the sockets of the eyes, at the end of which were broad red seeds, and the mouth and lower jaw were smeared over with black gum, in which were stuck seeds both red and white."[2]

[1] See also *Crania Ethnica*, by MM. de Quatrefages and Hamy, woodcuts, p. 195, also plate liv.

[2] Jukes's *Narrative of the Voyage of H.M.S. Fly*, vol. i. p. 274; Owen's *Catalogue*, 5350, 5351, 5355. Professor Owen states that 5355, the skull referred to in the above quotation, has the facial bones plastered over with a kind of ochreous marl, in which numerous seeds with a whitish pearly surface have been stuck.

Again, on p. 198, Mr Jukes states that the inhabitants of Maer, one of the Murray Islands, suspend near their houses, or place on the stumps of trees, skulls painted red. He also saw on Waier, another of the Murray Islands, a skull, old and weather-beaten, smeared with streaks of red paint and with several red flowers arranged on some twigs before it.

In the valuable collection of crania obtained by H.M.S. "Challenger," from Nares Harbour, Admiralty Islands, is one specimen, in which each orbit is filled with a black hardened earthy mass, in the centre of which is the valve of a small bivalve shell. A similar material has been used to fill up the hollow at the base of the skull, between the foramen magnum and the posterior nares, and the nasal cavity, and it has also been employed in the modelling of an artificial nose of a low aquiline form. In other respects this skull has not been artificially decorated, but the outer table of the bones of the vault shows a peeling off of their lamellæ, as if from exposure to the weather. Many of the other crania from the same locality are smeared with red pigment, but not so as to form definite patterns.

Mr Moseley, in his account of the natives of these islands,[1] states that on Dentrecasteaux Island a skull, having an ornament in the nose, was suspended to the front of a house, over the doorway, by means of a stick thrust through holes in the squamous parts of the temporal bones, but that the owner would not part with it. As the greater number of the crania collected by the "Challenger" at Nares Harbour have holes in the squamous temporals, they had, without doubt, been suspended in a similar way.

It is now known that the Andaman Islanders frequently wear a skull on the back of the body, suspended by a cord from the neck.[2] The skull is often smeared with grease and red ochre. In Dr Barnard Davis's collection are some specimens[3] in which all the surface of the calvarium, as well as the bones of the face, had been scored with very fine incised lines, running obliquely

[1] *Journal Anthrop. Inst.* vol. v., and *A Naturalist on the Challenger*, London, 1879.

[2] See illustrations from photographs in Dr Brander's paper "On the Andamanese," in *Proc. Roy. Soc. Edin.*, 2d Feb. 1880.

[3] 1552, 1762, *Supplement to Thesaurus Craniorum.*

across from each other, and making a small diamond-shaped pattern. Dr Davis also refers to similar crania described by M. de Quatrefages. In the Museum of the College of Surgeons of England, Professor Flower has described [1] a male Andamanese skull (1202) stained with red ochre, and adorned with tassels composed of threaded pieces of the shell of *Dentalium*, and containing within its cavity several valves of *Novaculina olivacea*. This skull was worn by the widow on her back. Dr Brander also describes the Andamanese as wearing necklaces formed of the metatarsal and metacarpal bones, the larger phalanges, and occasionally the vertebræ. A similar practice of wearing the bones of deceased relatives as ornaments of the person prevailed amongst the now extinct Tasmanian people, and some tribes of Australians carry, suspended by a string, human skulls, which they use as water-vessels.[2]

Both Captain Moresby [3] and Dr Comrie,[4] who visited the eastern part of New Guinea in H.M.S. "Basilisk," have pointed out that the natives wear the lower jaw as a bracelet, a band of grass between the two rami completing the circle. Hence it is difficult to secure human crania with the lower jaws attached to them.

But the practice of decorating and preserving the heads of the dead has not been limited to the races of the Malayo-Polynesian archipelago. Blumenbach figures (plate xlvii.) [5] the head of a Brazilian dried with the skin and hair. The mouth and orbits are filled with a hard bituminous material, whilst the edges of the closed eyelids are represented by a pair of the incisor teeth of the Capybara placed parallel to each other, and firmly fixed into the bitumen.

Dr Barnard Davis has in his collection the skull (1425) of a Charca, a Bolivian Indian,[6] which reached him in the condition of a prepared head, with all the integuments dried upon it, and with a profusion of long rich brown hair. Among the hair were two feathers, one blue, the other green, whilst a third feather was stuck in the mouth.

[1] *Osteological Catalogue*, part 1, 1879.
[2] Fig. 79 in *Thesaurus Craniorum*.
[3] *Discoveries in New Guinea*.
[4] "Anthropological Notes on New Guinea," in *Journal Anthrop. Inst.* vol. vi.
[5] *Decas Craniorum*, Göttingen, 1790.
[6] *Thesaurus Craniorum*, p. 249.

From these observations it will be seen that whilst the habit of preserving the heads and skulls of the dead has prevailed over a very wide range of country, and amongst different races, yet that the methods adopted have been by no means uniform, and have varied somewhat with the nature of the material at hand which could be used for purposes of decoration. Feathers, shells, mother-of-pearl, the incisor teeth of rodents, and tinfoil have all been brought into requisition. Pigments of various colours have been applied, from an irregular smear on the surface of the skull to patterns of a more or less elaborate character, designed either on the bones of the cranium or on the face. Sometimes, as by the Dayaks and Andamanese, a pattern has been engraved by some sharp instrument on the cranial bones themselves.

A very common practice has been to fill up the orbits with some composition of earth, or resin, or gum, and to simulate the eyes by sticking pieces of mother-of-pearl, or shell, or other bright objects into the material employed to fill up the orbit.

Occasionally an artificial nose has been constructed of wood, or clay, or some composition of earth with a resinous or gummy substance. In addition to the specimens described or referred to in a previous part of this communication, others have been put on record. Thus Mr Macgillivray, in his *Narrative of the Voyage of the Rattlesnake,* in writing of the Darnley Islanders,[1] says, "Several human skulls were brought down for sale, also a little shrivelled mummy of a child. Some of the former had the skin quite perfect, the nose artificially restored in clay mixed with a resinous substance, and the orbits occupied by a diamond-shaped piece of mother-of-pearl, with a black central mark."[2] In Dr Barnard Davis's collection is the skull of a male Dayak (1406), into which an artificial nose, made of wood and covered with tinfoil, of Bancan tin, has been inserted. Professor Flower also catalogues (744) the skull of a male Dayak, obtained in the neighbourhood of Sarawak, in which the orbits and nasal openings have been filled with wooden plugs; and a second male

[1] Vol. ii. p. 48.

[2] It is probable that specimen 1190 in Professor Flower's *Osteological Catalogue of the Museum of the Royal College of Surgeons of England* is one of these skulls, for it was obtained from Darnley Island by Professor Huxley, when assistant-surgeon on the "Rattlesnake."

cranium (745), also from near Sarawak, which has been similarly treated. This latter cranium, however, he thinks, presents more Melanesian than Malay characters, and may be of Papuan origin.

The masks described in this communication display a higher degree of artistic capacity on the part of the modeller than those above referred to. Not only a nose, but an entire face has been modelled in a composition applied to the facial bones, which has hardened on exposure, and has been subsequently decorated with paint and other adornments. It is worthy of note that the type of nose designed by the native artist differs in the two masks. In the smaller mask the nose is of a low aquiline form, swollen out at the sides, but with a sharp mesial bridge. The low aquiline nose of the "mud figure" has also a sharp mesial bridge, but the sides are more compressed. In the larger mask the nose is straight, moderately prominent, and compressed at the sides, which would seem rather to approximate in shape to the Malay type of nose, as described by Mr Wallace.[1] The nose of the smaller mask, again, corresponds rather with that of the Papuan in its aquiline form, but is not so large, arched, and high as Mr Wallace describes the Papuan nose to be, or as is figured on the natives of Redscar Bay, New Guinea, from a drawing by Mr Huxley, in the second volume of the *Voyage of H.M.S. Rattlesnake.*[2]

Artificial masks, made of various materials, have been described from the islands near New Guinea. Mr Jukes found in a hut on Mount Ernest human bones coloured with red ochre, and a mask or hideous face of wood, ornamented with the feathers of some struthious bird. He procured also from Darnley Island a mask or face of tortoise-shell, made to fit over the head, which was used in their dances. It was very fairly put together, with hair, beard, and whiskers, projecting ears, and

[1] "Man in the Malayan Archipelago," *Trans. Ethnol. Soc.* vol. iii.

[2] See also Mr Jukes's description of the Darnley Islanders :—"They had frequently almost handsome faces, acquiline noses, rather broad about the nostril, well-shaped heads, and many had a singularly Jewish cast of features." Mr Moseley speaks of the long Jewish noses of some of the natives of Humboldt Bay, on the north coast of New Guinea, and of some of the natives of the Admiralty Islands. Dr Comrie also states that the natives of New Guinea between East Cape and Astrolabe Bay, have aquiline noses.

pieces of mother-of-pearl, with a black patch in the centre for the eyes.[1] A similar mask made of tortoise shell was obtained, also from Erroob, by M. D'Urville, and is figured in vol. ii. of the *Atlas Pittoresque.*[2]

I have not, however, found any record of masks similar to those described in this communication, formed of the facial bones themselves, on which a face had been modelled. There can, I think, be no doubt that the larger of these two masks had been worn, and it is not improbable that, like the tortoise-shell mask above described, it had been used by the natives in their dances.

[1] This mask is figured on p. 178, vol. i. of the *Narrative of the Voyage of the Fly*. It was placed in the British Museum.

[2] *Voyage au Pole Sud*, pl. clxxxvi.

EXPLANATION OF PLATE XXX.

Fig. 1. The larger of the two Masks.
Fig. 2. The smaller of the two Masks.
Fig. 3. Profile view of the Skull from Warrior Island.

ON THE EFFECT OF CERTAIN ANÆSTHETICS ON THE PULMONARY CIRCULATION. By DAVID NEWMAN, M.B. *Reported on behalf of the Committee on Anæsthetics of the British Medical Association.*[1]

IN the last report of the Committee,[2] a series of experiments performed with the object of investigating the conditions of blood-pressure in animals under the influence of chloroform, ethidene, and ether was described, and, in view of the facts obtained therefrom, the Committee felt warranted in drawing the following conclusions:—

"1. Both chloroform and ethidene administered to animals have a decided effect in reducing the blood-pressure, while ether has no appreciable effect of this kind.

"2. Chloroform reduces the pressure much more rapidly and to a greater extent than ethidene.

"3. Chloroform has sometimes an unexpected and apparently capricious effect on the heart's action, the pressure being reduced with great rapidity almost to *nil*, while the pulsations are greatly retarded or even stopped. The occurrence of these sudden and unlooked for effects on the heart's action seems to be a source of serious danger, all the more that in two instances they occurred more than a minute after chloroform had ceased to be administered and after the recovery of the blood-pressure.

"4. Ethidene reduces the blood-pressure by regular gradations, and not, so far as observed, by sudden and unexpected depressions.

"5. Chloroform may cause death in dogs by primarily paralysing either the heart or the respiration. The variations in this respect seem to depend to some extent on individual peculiarities of the animals; in some the cardiac centres are more readily affected, in others, the respiratory. But peculiarities in the condition of the same animal very probably have some effect in determining the vulnerability of these two centres respectively, and they may both fail simultaneously.

"6. In most cases respiration stops before the heart's action; but there

[1] The Committee now consist of Joseph Coats, M.D., Pathologist, Western Infirmary, Glasgow; John G. M'Kendrick, M.D., Professor of Physiology, University of Glasgow; and David Newman, M.B., Pathological Chemist, Western Infirmary, Glasgow. Dr Newman became a member of the Committee on the appointment of Dr William Ramsay to the Chair of Chemistry in the University College, Bristol.

[2] *Journal of Anatomy and Physiology*, vol. xiii. p. 387, and *British Medical Journal*, 21st June 1879.

was one instance in which respiration continued when the heart had stopped, and only failed a considerable number of seconds after the heart had resumed.

"7. The use of artificial respiration was very effective in restoring animals in danger of dying from the influence of chloroform. In one instance its prolonged use produced recovery, even when the heart had ceased beating for a considerable time.

"8. Under the use of ethidene there was on no single occasion an absolute cessation either of the heart's action or of respiration, although they were sometimes very much reduced. It can, therefore, be said that, though not free from danger on the side of the heart and respiration, this agent is in a very high degree safer than chloroform.

"9. These results confirm and amplify those stated in a previous report, to the effect that ethidene does not compromise the heart as does chloroform. By the method of experimentation then employed, the effect on the blood-pressure could not be determined; and altogether the results here obtained are more exact and unequivocal."

Since the last report, amongst other lines of investigation, both clinical and physiological, we have been directing our observations to the study of the influences of the same anæsthetics on the pulmonary circulation; and it is to the experiments performed with this object that we now desire to call attention. One of the most striking effects of anæsthetic agents is the engorgement of the right side of the heart and the large veins near it. This has been directly observed by the Committee, and is well known. It is evidently a matter of importance to ascertain the cause of this phenomenon, which might be due to debility of the heart, to some change occurring in the lung resulting in obstruction, or to some influence on the circulation acting through the nervous centres governing it. The research now reported has reference to the effect on the pulmonary circulation.

At the very outset it was found necessary to devise a special apparatus for carrying on artificial respiration in the frog; so before considering the results of the experiments it will be requisite to describe it, and narrate the mode of procedure.

The apparatus, a drawing of which is shown in fig. 1, consists of two graduated cylinders, B and C, capable of holding 100 c.c. each, the former being a reservoir for air, the latter containing a supply of anæsthetic vapour. Associated with each of these is a series of tubes, the connections and uses of which may be seen

by referring to the drawing. From the pressure-bottle (A) passes a tube (a) which divides into three portions, two of which (b and c) pass under the keys (x^1 and x^2) to C and B, whilst the third branch passes downwards, and is fastened with a clamp the same as y^2. The glass cylinder C terminates in a T-tube (e), one

Fig. 1.

limb of which conducts to a flask (D) containing the anæsthetic, whilst the other passes to the manometer E. The upper part of the vessel B likewise terminates in a T-tube, the one limb leading to the manometer, the other (d) communicating with the air. From the manometer (E) passes a tube (f) going to the canula (h). The canula is different from what is commonly used, and

is represented on the upper right hand corner of fig. 1. It consists of a glass T-tube, one limb (that introduced into the glottis of the frog) of which is about 15 mm. in length; this, after being slightly constricted, terminates in a small ball.

Let us now explain the method of working the apparatus. The pressure bottle (A) contains a quantity of water, which, by reason of its elevated position, exerts a pressure upon the contents of B and C. There are a number of clamps used in closing the india-rubber tubing at various points—the action of these will be explained as we go along, and understood by referring to the drawing. Supposing now that we wish to carry on artificial respiration with air or anæsthetic vapour. The clamp to the right of *b* is opened, whilst all the others are closed. To inflate the lungs with air open the key x^2, and with anæsthetic vapour x^1, and to empty the lungs open x^3. It will thus be seen that, to carry on artificial respiration with air, all that is necessary is to open and close alternately x^2 and x^3, and with anæsthetic vapour x^1 an x^3. When all the vapour in C is displaced by water, and it becomes necessary to have a fresh supply, close the clamp to the left of *b*, open y^2 and allow the water to escape through the tube, the prolongation downwards of *c*, by removing the clamp and opening the key x^1, the anæsthetic vapour will then be sucked from D into C, thereupon close all the clamps, open the one to the left of *b*, and begin the respiration afresh. When a supply of air is wanted, open y^1 in the place of y^2; *l* is a cork plate upon which the frog is laid.

One of the first difficulties in conducting the experiments was the trouble experienced in keeping the canula in position after its introduction into the glottis of the frog, and several attempts were made to fasten it in by means of a ligature. This method was soon given up on account of its awkwardness. The canulæ shown in fig. 1 are found to answer very satisfactorily: it is advisable, however, to have them of several sizes, this being necessary on account of the differences in the dimensions of the glottis in individual frogs. By passing a pin through the upper and lower jaw of the frog, so that it is external to the angle formed by the two limbs of the canula, the canula is kept in perfect position without the use of a ligature. To complete the manipulative portion of the experiment, it is now requisite to

make an incision in the thoracic wall, through which the lung is protruded: this is best accomplished by placing the frog upon its back, making a longitudinal cut of about three quarters of an inch half-way between the spine and sternum, beginning about a quarter of an inch below the axilla. Having inflated the lung, it passes through the incision just mentioned, and the circulation may be now watched under the microscope with a power of from 50 to 300 diameters.

In conducting the experiments certain points require to be observed—(1) The quantity of air or anæsthetic vapour passed into the lungs during inhalation, (2) the pressure used, and (3) the time occupied. The first of these was regulated by measurement, the second indicated by the manometer. To save the trouble, however, of measuring the quantity for each inspiration, the following method was adopted:—The lung having been distended by a suitable quantity of air (from 3 to 4 c.c., according to circumstances), and a certain point brought into focus, the condition of the circulation was observed. By opening the key x^3 the lung collapsed. Now, instead of inflating, and again focusing, the microscope was kept fixed, and air or anæsthetic vapour, as the case might be, passed into the lung till, by distention, the same point as before came into view. The focus may be as accurately fixed by gently pressing upon the keys x^1 or x^2, as by the adjustment of the microscope. This method had not only the advantage of submitting the same portion of lung for examination, but also guaranteed its equable distention throughout the experiment, and so obviated fallacies which might arise from variation in the quantity, or of the pressure of the atmosphere in the lung. The average quantity of air or vapour used to inflate the lung of a good-sized male frog equals 4 c.c., and the pressure 55 mm. (water manometer). During the experiment the exposed surface of the lung was kept moist with a few drops of saliva applied occasionally. We will now give a few examples from a series of experiments.

EXPERIMENT I.—A frog was placed in a bell-jar containing a piece of blotting-paper saturated with chloroform, the web of the right foot (the one to be subsequently examined) being, however, kept outside the jar. In two and a quarter minutes, when reflex action was destroyed, the canula was introduced into the glottis, the frog laid upon the cork-plate, and its right lung exposed, as described above. On inflating the

lung with air, the circulation both through the capillary and large vessels was found to be active—pulse 18 per minute. Artificial respiration was now carried on by means of the apparatus, 50 c.c. of an atmosphere containing chloroform being inspired in fifty seconds. Fifteen seconds after the first inspiration a distinct change could be observed in the rapidity of the flow of blood through the capillaries, even though the circulation in the larger vessels was unimpaired, and the number of the heart's impulses remained unchanged. By fifty seconds, however, not only had the pulse become diminished in number to a fourth, but the capillary circulation of the lung and web ceased, and by seventy-five seconds the flow of blood through the large vessels both of the lung and foot entirely stopped, whilst the heart-beats, as observed through the thoracic walls, were four per minute. Air was now substituted, and 400 c.c. passed through the lungs in eight minutes. By this time the heart-beats had increased to nine per minute, and the blood began to flow slowly through the larger vessels of the lung. No movement could be detected in the web. When, however, 600 c.c. of air had been expended in artificial respiration (the time occupied being twelve minutes) the pulse rose to 15, the flow of blood through the lung became as vigorous as before, whilst the circulation in the foot gradually increased, and in a few minutes became as active as before chloroform was administered by artificial respiration.

Experiment II.—This experiment was performed in exactly the same manner as the last, with the exception that ethidene dichloride was used in the place of chloroform. Instead of taking two and a half minutes, as with chloroform to lose reflex action, it required nearly five minutes. On exposing the lung, its substance was found to be brighter in colour, and the circulation more active than when chloroform was administered. The pulse was twenty-three per minute; 250 c.c. of ethidene vapour were now passed into the lung (time 180 seconds). Forty-five seconds passed before any change could be observed. In 105 seconds, however, the capillary circulation in the lung and web ceased, and in 180 seconds the flow through the vessels stopped, at which time the heart's impulses were seven per minute. The stoppage of the circulation was almost simultaneous in the web and lung. Artificial respiration was now carried on with air. After 100 c.c. had been given (time 50 seconds), a slight movement of the corpuscles was observed in the vessels of the lung, and in seventy-five seconds in the foot. When 250 c.c. (time 120 seconds) of air had been passed through the lung the capillary circulation gradually became established, and by the time (240 seconds) 250 c.c. had been respired it was as active as at the beginning of the experiment, and the pulsations of the heart rose to 18 in the minute.

Experiment III.—In this experiment ether was used as the anæsthetic. The frog, placed in an atmosphere of ether, took eight and a half minutes to lose reflex action (pulse 24 per minute). The naked eye and microscopic appearances of the lung were much the same as when ethidene was administered. 500 c.c. of ether vapour were given before the circulation in the large vessels of the lung could be stopped (time twelve minutes), whilst the capillary circulation required 175 c.c.

(time 110 seconds) before any change could be noticed, and 300 c.c. to make it stop completely, the pulse being 6½ in the minute. The frog was now made to inhale air. When 150 c.c. had been given, the circulation began to be re-established in the larger vessels, the pulse being nine per minute, and when the air passed into the lungs amounted to 200 c.c., the capillary circulation also returned to what it was before the ether was given artificially. Chloroform vapour was now given for 180 seconds to the same frog with the following results:—In fifteen seconds a marked change was observed in the capillary circulation, in thirty it stopped, and in forty-five the flow through the large vessels ceased.

Before passing to the consideration of the minute changes in the lung, let us contrast the following points as regards the comparative effects of chloroform, ethidene, and ether:—

I. The time required to produce complete stoppage in the pulmonary circulation.
II. The amount of anæsthetic vapour employed.
III. The quantity of air necessary to re-establish the circulation in the lung.
IV. The time occupied in restoring the circulation.

By glancing at the above experiments, it is in the first place to be observed that the changes produced by the three anæsthetics employed differ only in the rapidity of their occurrence, not in kind. Thus chloroform may be placed at one extreme, ether at the other, whilst ethidene occupies an intermediate position. The relative effects of these anæsthetics are shown in the following table, constructed from the above experiments, which were chosen as showing strictly average results:—

	Chloroform.	Ethidene.	Ether.
I. Time required to produce complete stoppage of pulmonary circulation,	75 seconds	180 seconds	270 seconds
II. Amount of anæsthetic vapour employed,	50 c.c.	250 c.c.	500 c.c.
III. The quantity of air necessary to re-establish circulation in lung,	600 c.c.	250 c.c.	200 c.c.
IV. Time occupied in restoring the circulation,	720 seconds	240 seconds	180.
V. Heart's impulses before artificial respiration,	18	23	24
VI. Heart's impulses when circulation has stopped,	4	7	6½

The difference in the action of these anæsthetics will be seen from the above table not only to depend upon a variation in the amount of anæsthetic vapour required to produce complete stoppage of the circulation in the lung, but also in the want of uniformity in the quantity of air necessary to restore it to its former condition. For instance, the chloroform vapour necessary to stop the circulation is 50 c.c. administered in 75 seconds; ethidene, 250 c.c. administered in 180 seconds; and ether, 500 c.c. in 270 seconds. Now, it might be expected that the amount of air required to eliminate the ethidene taken up by the lung during its exposure to the action of 250 c.c. of vapour, should be greater than that needed to free the circulation from the effects of 50 c.c. of chloroform, and more particularly when it is observed that the time during which the ethidene vapour was in contact with the lung, amounted to almost two and a-half times as long as the chloroform. But this is not the case. In fact the contrary may be affirmed. The longer it takes to place the circulation in abeyance, and the greater the amount of anæsthetic vapour used, the shorter is the time requisite to re-establish the pulmonary circulation, and the smaller the amount of air necessary to do so; in other words, the length of time and the amount of air employed in artificial respiration with the object of restoring, is in an inverse ratio to time and amount of anæsthetic vapour required to stop the circulation. The impulses of the heart, both in relation to their frequency and other characters, will be more carefully studied further on.

The next question which presents itself for our consideration is one of considerable importance and interest, namely, what are the changes which take place in the lung when anæsthesia is pushed to its utmost point, and how are these alterations to be explained? We will first attempt to describe the changes, and then proceed to the consideration of the causes which bring them about.

When anæsthetics are administered in excessive quantities, the first change noticed in the circulation in the lung is a diminution in the rapidity of the flow of blood in the capillaries, and this, notwithstanding that the number of the heart's impulses remain unchanged, and the circulation through the larger vessels is unimpaired. Very shortly after this, instead of the

flow of blood being constant, it gradually becomes intermittent first in the capillaries, afterwards in the arterioles, and subsequently in the larger vessels. This intermission in the flow of blood is followed by a swinging to and fro movement of the corpuscles just previous to the stoppage of the circulation through the capillaries.

It must now be observed that the stoppage of the circulation in the lung takes place first in the capillaries, then in the arterioles, and last of all, in the larger vessels: further, that the sequence in recovery is exactly the reverse. Again, it is to be

Fig. 2.

noticed that the circulation in the foot stops, not previous to, but shortly after that of the lung, and its re-establishment never occurs before, but always subsequent to the restoration of the pulmonary circulation. The more minute changes to be observed in the lung are represented in the woodcuts figs. 2 and 3.

When the lung is *not* over-distended, and the amount of anæsthetic vapour administered moderate, a plexus of irregularly-shaped meshes may be observed, formed in the alveoli by the capillary vessels. The diameter of the capillaries varies from ·0225 to ·0275 mm., whilst the size of the corpuscles may be laid down as from ·020 to ·025 mm., and the enclosed spaces

from ·040 to ·060 mm., or even more. The meshes (fig. 2, B) not only vary in size amongst themselves, but also at different times, according to the pressure exerted upon the air in the pulmonary sac. So much is this the case, that should the lung be over-distended, the meshes become so stretched that they diminish the calibre of the capillaries, and so retard, or even prevent, the flow of blood; hence the necessity of having the lung equally inflated throughout the experiment. Whilst the circulation is active, the contour lines of the flat, irregular-

Fig. 3.

shaped alveolar epithelium (fig. 2, D) of the meshes, as well as their nuclei (fig. 2, C), may be distinctly seen, and the outline of the capillaries (fig. 2, B) is well marked. When, however, the anæsthetic has been pushed so as to stop the pulmonary circulation, the individual epithelium cells become at first indistinct; the nuclei also become less evident and subsequently disappear, so that instead of presenting the aspect of cellular structures, the meshes enclosed by the capillaries show themselves as if they were spaces filled with granular protoplasm. Further, the limitations of the meshes themselves (fig. 3, B) become so indistinct, that it is with considerable difficulty that

the course of the capillaries can be traced. This difficulty is increased by the tendency of the corpuscles to aggregate themselves at certain points (fig. 3, A), and so leave empty spaces where the capillaries, partly on account of this deficiency, become invisible (fig. 3, B). The want of clearness in the definition of the capillaries is not, however, entirely due to the absence of corpuscles, for even where the corpuscles are abundant (fig. 3, A), the capillary walls are less distinct than when the circulation is active. As regards the calibre of the arterioles and capillaries, it may be roughly stated that the former contract a sixth, the latter a ninth from what they were previous to the administration of the anæsthetic vapour by artificial respiration. The causes of this contraction will be considered hereafter. Should repeated supplies of air be now passed into the lung, the condition of that organ will be restored to what it was before the anæsthetic was given.

The corpuscles themselves appear also to be altered by the action of the anæsthetic vapour, in so far that at some points they appear as if they had become completely disintegrated and their place filled by a mass of a reddish coloured material which disappears on the re-establishment of the circulation.

The granular appearance presented by the contents of the meshes and the disintegrated condition of the corpuscles are not represented in fig. 3, in which figure the outline of the corpuscles is too distinctly shown.

In order to determine the effect of anæsthetics upon the cardiac impulses another series of experiments became necessary. These experiments were performed by means of a very complete recording apparatus in the Physiological Laboratory of the University of Glasgow. A sheet of paper 8 feet long and broad enough to accommodate ten tracings at different levels, was adapted to the cylinders so that a continuous tracing of 80 feet, if necessary, might be obtained; at the same time a record of time was taken corresponding to each individual tracing, and, besides, by means of electro-magnetic arrangements, the periods at which anæsthetics were administered or certain changes observed were recorded. Fig. 4 shows selected portions of these tracings.

The method adopted in recording the movements of the heart,

was very simple. The heart was supported upon a small stage

Fig. 4.

so as to prevent the movements occasioned by artificial respiration affecting the tracings of its impulses. A lever 20 cm. long

was placed obliquely across the heart in order to rest both upon the auricle and ventricle, so that the first portion of the up-stroke might correspond with the contraction of the auricle. When the ventricular contractions closely follow those of the auricle the ascent line is straight, and no indication of the latter as separated from the former can be detected, whereas if the ventricular contractions are delayed the lower portions of up-strokes become curved (tracing VIII. fig. 4).

With the purpose of instituting a standard of comparison a tracing of the heart's impulses is shown in fig. 4, tracing I., where the frog was under the influence of curare. The heart's impulses were 40½ per minute, whilst the period of activity may be said to occupy 2·5 hundredths of a minute, so that the period of rest, as far as indicated by the tracings, may be regarded as *nil*.

Chloroform was now given for fifteen minutes by means of artificial respiration to the curarised frog, and another tracing taken (fig. 4, tracing II.). It may now be observed that the heart's beats are 23 per minute, and still the period of rest is not distinctly marked. In these tracings the up-strokes are rapid, and the periods occupied in the contractions are not great. Tracings III. and IV. show the pulsations of the heart under the influence of ether, the former immediately on the heart being exposed, the latter after ether had been administered for seven minutes by artificial respiration. The pulsations in III. and IV. are 21 and 19 respectively, so that as contrasted with tracing I. they may be said to be diminished in number by about a half. The period of rest is not well marked in either of these tracings. Tracings V. and VI. were taken from a frog under the influence of ethidene, the one on exposing the heart, the other after ethidene had been given by artificial respiration for five minutes.

Let us now examine these tracings more carefully. In tracing V. the pulsations are 16 per minute. The period of activity occupies about 2·8, and that of rest 3·5 hundredths of a minute. The ascent line is not quite straight, there being a slight curve both at the apex and base, the apex is rounded and the descent line slightly sloped. In tracing VI. the impulses are diminished in number to seven per minute. This diminution will be seen to be due to two causes—first and principally, to prolongation of the period of rest; and second, to lengthening

of the period of action, so that not only are the spaces between the waves greater, but the intervals between the origin of the ascent lines and the termination of the down-strokes are also increased. To represent this in figures it may be said that the period of activity equals a little more than four-hundredths, and the period of rest ten-hundredths of a minute. Tracings VII., VIII., IX., and X. are those of a frog under the influence of chloroform. Tracing VII., immediately on exposure of the heart; VIII., after artificial respiration with chloroform for two minutes, 150 c.c. of vapour having been employed; IX., recovery after artificial respiration with air for three minutes; and X., after giving 200 c.c. more of chloroform-vapour, the time occupied being two minutes. The impulses in tracing VII. are eleven per minute. It will be observed that from the termination of the down-stroke to the beginning of the following ascent line there is a gradual rise in the tracing. This is due to the slow filling of the cavities of the heart. The up-strokes are slightly curved, the apices rounded, whilst the descent-lines are almost straight. By pushing the chloroform by means of artificial respiration we always get tracings similar to what is represented in VIII. Take for instance the large wave in the centre of the tracing, instead of the up-stroke arising directly from the basement line it is preceded by a small wave (A^1), corresponding with the contraction of the auricle. From the apex of this wave it rises slowly so as to form the ascent line, which terminates in a rounded apex. The descent line frequently terminates in a smaller wave (tracing X. A^2), which also corresponds with a contraction of the auricle. It is further to be noted that the auricular contractions (tracing VIII. A^2) are not always followed by corresponding auricular movements, the auricle continuing to contract at regular intervals although the ventricle ceases to respond.

Let us now consider the facts demonstrated by the tracings placed alongside the changes observed in the lung, by means of the microscope.

It is evident that the interference with the proper action of the heart accounts to a considerable extent for the changes in the pulmonary circulation and tissue. Thus the slowing of the circulation through the lung and the diminution of the calibre

of the arterioles and capillaries correspond exactly with the impairment of the heart's impulses; but, then again, it may be questioned, how far the stoppage of the heart depends upon increased resistance to the flow of blood through the pulmonary vessels. We have shown above that when the lung is exposed the current of blood is continuous, there being no intermittent movement, as a result of the ventricular contractions; when, however, anæsthetics are administered in larger quantities, the flow becomes interrupted, the arterioles and capillaries diminish in calibre, and certain changes are observed in the pulmonary tissue. The changes in the diameter of the vessels may be regarded as a result of a slowing, and less forcible contracting of the ventricle, or it may be due to local effects of the anæsthetic upon the lung, producing greater resistance to the flow of blood, and so preventing the heart emptying itself. The latter idea is supported by the fact that when the animal is deeply under the influence of the anæsthetic, particularly chloroform, the heart is greatly distended. Another fact which must not be forgotten is the change in the condition of the corpuscles and the capillaries. The mutual relationship of these may be so altered by the direct action of the anæsthetic, that the force of the heart required to propel the blood through the pulmonary vessels is increased, whilst by reason of the action of the anæsthetic upon the heart the power at its disposal is considerably diminished. The disintegration of the blood corpuscles, as pointed out above, shows distinctly that the anæsthetic-vapour has a direct effect upon the blood.

The facts obtained from these researches seem to us to warrant the following conclusions:—

1. As in the experiments on the effects of the anæsthetics upon the blood-pressure, it may be stated that chloroform produces the most immediate effect, ether the least, whilst ethidene occupies an intermediate position.

2. The quantity of air and the length of time required to restore the circulation in the lung is in an inverse ratio to the amount of anæsthetic-vapour, and time necessary to stop it.

3. The changes produced in the lung are the same in all, the only difference being in the rapidity of their occurrence.

4. The anæsthetics produce the following changes in the lungs

—(1) Slowing and ultimate stoppage of the circulation in the lung, first in the capillaries, then in the arterioles, and subsequently in the larger vessels; (2) the epithelium cells of the meshes and their nuclei are no longer apparent; (3) the capillaries contract slightly, and their walls become less distinct or even disappear from view, and the enclosed corpuscles may become more or less disintegrated.

5. The effect of ether and ethidene upon the heart after artificial respiration for seven and five minutes respectively, is simply to produce a slowing of the impulses, ethidene having the most marked effect. Chloroform not only produces a slowing of the pulse, but the ventricular contractions are delayed and slightly separated from the auricular, and an auricular contraction may immediately follow the ventricular. The auricular contractions frequently occur without any corresponding ventricular movements.[1]

The Committee purpose giving a complete report of their investigations up to the present time at the approaching meeting of the British Medical Association at Cambridge.

[1] In connection with this point Dr Coats is at present engaged with an investigation into the effect of anæsthetics upon the cardiac ganglia.

NOTE ON A NEW METHOD OF PRESERVING THE COLOURS OF TISSUES. By HOWARD BENDALL, *Student of Medicine, University of Edinburgh.*

IT would undoubtedly be a great advantage if the specimens in our Anatomical Museums could be preserved with their original colours unaltered; but, unfortunately, hæmoglobin and most of the other pigments found in the tissues are dissolved out or destroyed, to a greater or less extent, by all the preservative fluids which are usually employed. If a piece of fresh tissue be placed in commercial alcohol it very soon becomes bleached, and the fluid becomes at the same time discoloured by solution of the colouring matters. Hæmoglobin is soluble in almost every known fluid, with the exception of absolute alcohol, which, however, causes great shrinkage of the soft parts, and is, moreover, too expensive to be very generally employed. Solutions of chloral hydrate have been used (and with great advantage in many cases); but here again, although the colouring matters are by this means retained unaltered, yet they are not thereby rendered insoluble, and hence they tend to pass out into the fluid, leaving the tissues partially decolorised. Other media have been tried, but all have a similar imperfection. By baking or otherwise heating the tissues, the pigments are so altered as to be rendered insoluble in alcohol; but, in addition to the tediousness of the process, the action of alcohol is then to turn them black in the course of time, and hence this method is but little employed, except with the object of demonstrating large extravasation and similar changes.

Now it is a distinguishing characteristic of hæmoglobin that, although a crystalline body, it is not diffusible; and hence it occurred to the writer that if specimens could be coated with a transparent membrane of a homogeneous nature, the colouring matters would be preserved *in situ*. For this purpose let a quantity of isinglass or transparent gelatine be taken and steeped in excess of cold water for twenty-four hours, and then, after draining off the supernatant fluid, be dissolved by heating over a water-bath. The specimen is then taken, and, after being carefully wiped to remove superfluous moisture, is either plunged in the liquid gelatine or brushed thoroughly over therewith by means of a camel's-hair brush. After having received an uniform coat, the specimen is suspended in a cool and dry atmosphere for two or three hours, until the gelatine has had time not only to set, but to dry slightly on its external surface; it may then be suspended in a jar of alcohol, taking care that it be not allowed to rub against the sides of the jar for the first twenty-four hours. The alcohol, by its dehydrating power, rapidly removes the excess of water in the gelatine, and dries it up to a thin varnish-like, and (if suitable gelatine be employed) perfectly transparent coat, through which the pigments are unable to pass out. The alcohol employed should not be diluted, for if this be

done the gelatine remains soft and easily comes off. By this means I have been enabled to preserve, in an almost unaltered condition, portions of muscle, liver, &c., for over four months (the period over which my investigations have extended); and not only so, but more delicate gradations of colour, such as are seen in an atheromatous aorta, for example, are well maintained.

It is as well to point out that this method is not suitable for such tissues as contain very much blood—*e.g.*, the spleen—nor for cyanotic organs; for in such cases the blood pigment is carried to the free surface, and deposited beneath the gelatine in a layer which may be so dense as to give a darkened and discoloured appearance to the specimen.

Nevertheless, for most tissues the above method has hitherto yielded highly satisfactory results, and has the additional advantage that the alcohol does not become muddy or discoloured, and hence does not require to be frequently renewed.

VARIATIONS IN MYOLOGY. By J. MACDONALD BROWN, *lately Assistant-Demonstrator of Anatomy in the University of Edinburgh.*

WHILE acting as Demonstrator of Anatomy in the Anatomical Rooms of the Owens College, Manchester, I was privileged to observe some very interesting exceptions to ordinary human myology. The most striking of these were the following:—

I. *Levator Costæ Primæ.*—A slender muscle, taking origin from the superior border of the scapula, and partly from the supra-scapular ligament. It was found to end in a rounded tendon, which was inserted into the first rib, immediately external to its cartilage. It derived its nervous supply from the supra-scapular nerve. The muscle existed on both sides of the body.

II. *Levator Claviculæ.*—This muscle, as indeed the above also, has been frequently noticed by anatomical observers. What, however, makes this levator claviculæ specially interesting is the fact that, having subsequently made dissections of the muscular system of the Chimpanzee, I found the muscle in that animal to be identical in origin, form, insertion, and nervous supply with the one in the human subject. In both cases it arose from the anterior tubercles of the 1st and 2d cervical vertebræ, passed downwards and outwards, and was inserted into the posterior surface of the clavicle rather external to its middle. Its nervous supply was derived from the 2d cervical nerve. The muscle only existed on one side of the body.

III. In this case the *thenar* muscles were almost entirely awanting. The adductor pollicis was the only one present, and even it was extremely rudimentary. The student who was dissecting the right hand called my attention to the peculiarity; but the dissection was

too far advanced to admit of a minute examination of the configuration of parts. I was, however, fortunate enough to secure the left hand before its dissection had been begun, so that I was therefore enabled to make a careful examination of the condition. The thenar eminence was practically lost, the external aspect of the palm being much flattened. When the skin, fasciæ, &c., had been removed, it was found that the muscles of the ball of the thumb were entirely awanting, with the exception of the adductor. The latter was a very rudimentary muscle, but had the ordinary origin, insertion, and relations.

Although the muscles themselves were absent, yet their place was occupied by a series of ligamentous flattened bands, connected on the one hand with the tendons of the flexor longus pollicis and flexor digitorum sublimis, and on the other with the bones of the thumb. These fibrous bands, three in number, were attached to the above tendons immediately after they had emerged from under the anterior annular ligament.

Their exact bony attachments could not be defined, as they had become blended together before they reached the proximal part of the 2d phalanx. When the flexor tendons were drawn upon, the thumb was abducted and slightly opposed.

No history of any nervous lesion or of progressive muscular atrophy could be ascertained, but there was strong evidence against the presence of the latter in the fact that the hypothenar muscles were normal in size, and that there was no marked wasting of any of the other muscles of the body.

Dr D. J. Cunningham, of Edinburgh University, in his able paper on "The Intrinsic Muscles of the Mammalian Foot," describes an arrangement in the pes of the *Dasypus sexcinctus* which much resembles the condition I have described. He states that "where any of the muscles were absent, their place was taken by fibrous bands having the same connections and dispositions as those muscles of which they were the substitutes."[1]

[1] *Journal of Anat. and Phys.* March 1880.

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SUR LES PHÉNOMÈNES ELECTRIQUES DU CŒUR À L'ÉTAT D'ACTIVITÉ, par TH. W. ENGELMANN. *Archives Néerlandaises*, t. XV.

(*Abstract by George A. Gibson, M.B.*)

SOME years ago Professor Engelmann of Utrecht instituted a series of experiments on the electric phenomena of the heart in a state of repose, which were carried on with the assistance of Drs Nuel and Pekelharing. The results of these were reported to the Royal Academies of Belgium and of Amsterdam. A continuation of the work by Engelmann alone was published in 1875, and since then he has studied the phenomena of the heart in action.

General plan of the experiments.—The hearts were those of large frogs, carefully removed and placed in the moist chamber. The stimulation was either direct, by excitation of the ventricle itself, or indirect, by acting upon the ventricle through the auricle. The stimulation was caused by the interruption of an induced current, or by the differential rheotome of Bernstein as modified by Du Bois-Reymond and Engelmann.

The electrodes of excitation were composed of platinum points isolated almost up to their extremities, these being sometimes placed upon and sometimes introduced a certain depth into the heart muscle. To receive the current from the ventricular substance electrodes of clay were used. To avoid pressure on the moving object they were modelled out of very soft clay, and their points were each further provided with an end, made either of cotton moistened with a ½ per cent. solution of sodium chloride, or of mesentery.

As soon as the stimulation was produced the circuit of the exciting current was broken, and as soon as the heart current was derived the galvanometer was shut out of the circuit, so that the observation was made from the action of a single stimulus. After derivation extending to a duration of 0·03 – 0·08 sec., the extent of the action could be recognised with sufficient exactitude and without the necessity of using an instrument with the sensibility exalted to an embarrassing extent.

General action of the surface of the heart under the influence of direct and indirect stimuli.—The current was derived from the exterior of the ventricle at two points, inactive in repose, and unequally

removed from the part excited. With *direct* stimulations of the ventricle, of 78 experiments 47 gave evidence of the stimulation by deviation of the galvanometer mirror in opposite directions, the electrode nearer the point of excitation being firstly negative and secondly positive relatively to the other. In the other 31 experiments the positive action was absent, in 26 the initial indifference being restored, and in 5 a slightly negative condition being left. *In all these cases,* therefore, *the nearer point at once showed a negative action.*

This result was quite independent of all the other conditions of the experiments. With stimuli applied at any part of the ventricle, and with the electrodes of derivation at any part as well, the results were constant. The first conclusion to draw from these facts is *that from the time of excitation each part of the ventricle acquires transitorily a negative electro-motive activity, and that, starting from the stimulated part,* no matter where it may be, *this negativity propagates itself in all directions over the heart.*

When the ventricle was stimulated by *the intermediation of the auricles,* a negative activity, usually followed by a positive, was derived, and this result was also seen when the heart beat spontaneously. The negative action did not show itself until the termination of auricular action, and could not, therefore, be due to it.

Particulars relative to the form and course of the oscillation.—Engelmann has expressed the course of each electric current by a curve, of which the abscisses are proportional to the intervals of time from stimulation, and the ordinates to the deviation of the galvanometer needle. The curves are remarkably alike.

The oscillation began at the point excited immediately after the application of the stimulus. The mean increase of negativity was 0·09 sec., and the curve shows that the increase was continuous, shown as a nearly straight line, slightly accelerated at first. The continuous nature was seen even when the time of excitation was reduced to a minimum, as well as when the stimulus was applied through the auricles. This is another proof that the systole of the heart is a simple contraction and not in the least tetanic in its nature.

The stage of decreasing negativity was usually somewhat longer. It almost always began at the cessation of the increase without any interval, but was more complicated than the increase, and lasted on an average 0·151 sec. At the termination of the negative oscillations, the needle, as in most of the experiments, showed a positive force, which was abruptly stopped, as Engelmann suggests, by the arrival of the negative current at the more distant electrode. The mean duration of the positive oscillation was during increase 0·057 sec. and during decrease 0·050 sec.

Electro-motive force of the oscillation.—Under this head the author informs us, that as regards the relation between the intensity of the excitation and the force of the oscillation, the latter entirely depended upon the condition of the cardiac muscle, not upon the intensity of the stimuli, and as life disappeared the force of the oscillations gradually diminished.

Rapidity of propagation of the negative wave in the heart.—The determination of the speed with which the electro-motive current traverses the heart has been made with much care, and the results, briefly stated, show that the rapidity became less the longer the time which had elapsed from the setting-up of the preparation. During the first half-hour the rate of transmission was about 35–40 mm. per second, during the succeeding half-hour about 20 mm. per second, and during the third half-hour about 15 mm. per second.

REPORT ON THE CASE OF THE LATE DR E. A. GROUX. By DR CHARLES JEWETT, *Annals of the Anatomical and Surgical Society of Brooklyn, New York*, vol. i. p. 7, and p. 99.

(*Abstract by George A. Gibson, M.B.*)

RECENT observations on cleft sternum in Germany[1] and America,[2] as well as in this country,[3] have recalled the interest formerly felt in the subject when Herr Groux travelled the civilised world to exhibit himself to the scientific world, and his recent death has enabled American anatomists to compare the surmises made with regard to the relations of the malformation during the lifetime of its subject with the facts as they stand after death.

When at rest the interval between the two halves of the sternum was one inch, by forcible approximation they could be brought within one quarter of an inch of each other, and by forcible separation the gap could be increased to two inches. The mid-sternal space was occupied by a pulsating tumour which was by different observers considered to be either the great veins and right auricle, the right auricle, the right ventricle, or the aorta.

Two days after the death of Dr Groux, an autopsy was made in presence of a large number of scientific men of Brooklyn and New York. After ligaturing the trachea, to prevent any displacement of the thoracic organs by collapse of the lungs, an incision through skin and superficial fascia in the middle line opened directly into the anterior mediastinum; no other tissue was found bridging the space between the lateral halves of the sternum. The heart was normal in shape and size, but somewhat higher than usual, the apex reaching the upper border of the fifth left rib. The right auricle was quite to the right side, and the right ventricle occupied the position of the pulsating tumour in the medio-sternal space.

The sternum was formally presented to the Anatomical and Surgical Society by the widow of Dr Groux, and is now in the museum of the society. The following remarks are quoted from the description of

[1] Dr Franz Penzoldt, *Deut. Arch. f. klin. Med.* xxiv. Bd. s. 513.

[2] Dr J. T. Hodgen, *Amer. Pract.* Oct. 1878.

[3] *Journ. Anat. and Phys.* Oct. 1879, Drs Gibson and Malet; Prof. Turner, *ibid.*

pathological specimens in the museum :—"This sternum, from the body of the late Dr E. A. Groux, presents a complete median fissure of the bone. There is little or no deficiency of bony substance, the malformation resulting simply from failure of union between its lateral halves. The bony segments deviate somewhat in relative size from their usual proportions. The two halves of the cleft bone are separated by an interval of 1 inch at the level of the first costal cartilage. The width of the cleft at the widest part, the junction of the upper and middle thirds, is 1 inch and $\frac{4}{10}$ths. Below, the lateral halves of the sternum are united by an arthrodial joint. This joint is limited to the lower segment of the gladiolus, connecting its opposite halves. The cartilages which invest the articular surfaces blend below with the xiphoid appendix. The costo-sternal articulations are normally disposed, except the fifth, sixth and seventh. These are placed higher than usual, so that the seventh costo-sternal articulation falls at the junction of the third and fourth segments of the gladiolus."

The sternum, therefore, in this celebrated case, closely resembles that in the Anatomical Museum of the University of Edinburgh, described by Professor Turner, as referred to in the footnote. The relations of the two halves, and the articular junction uniting them are almost similar in both cases.

Finally, we would seize this opportunity to convey our hearty congratulations to our brethren in Brooklyn upon the establishment of a society so well calculated to foster the progress of scientific medicine, as well as upon the publication of such an interesting and beautiful periodical as the "Annals."

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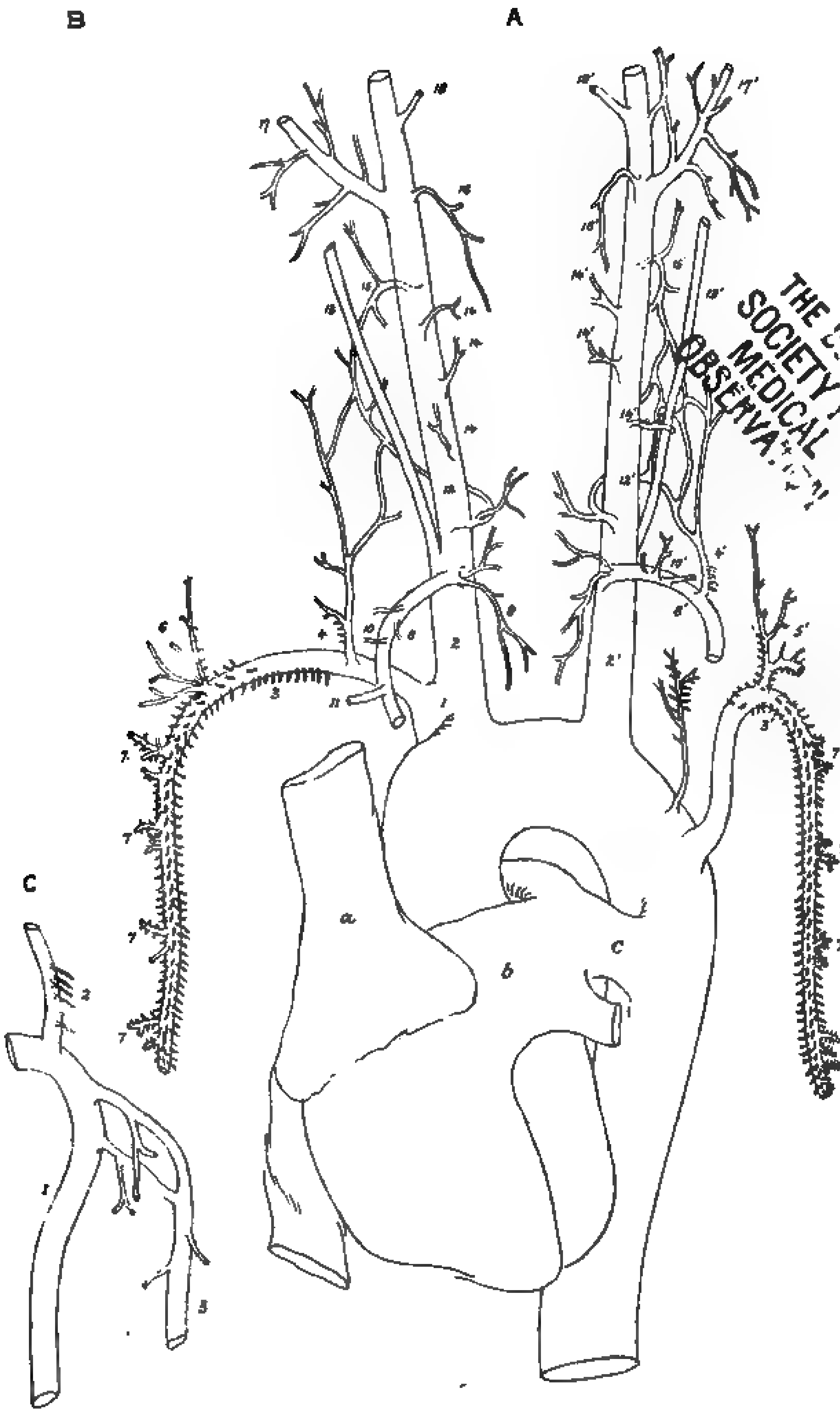

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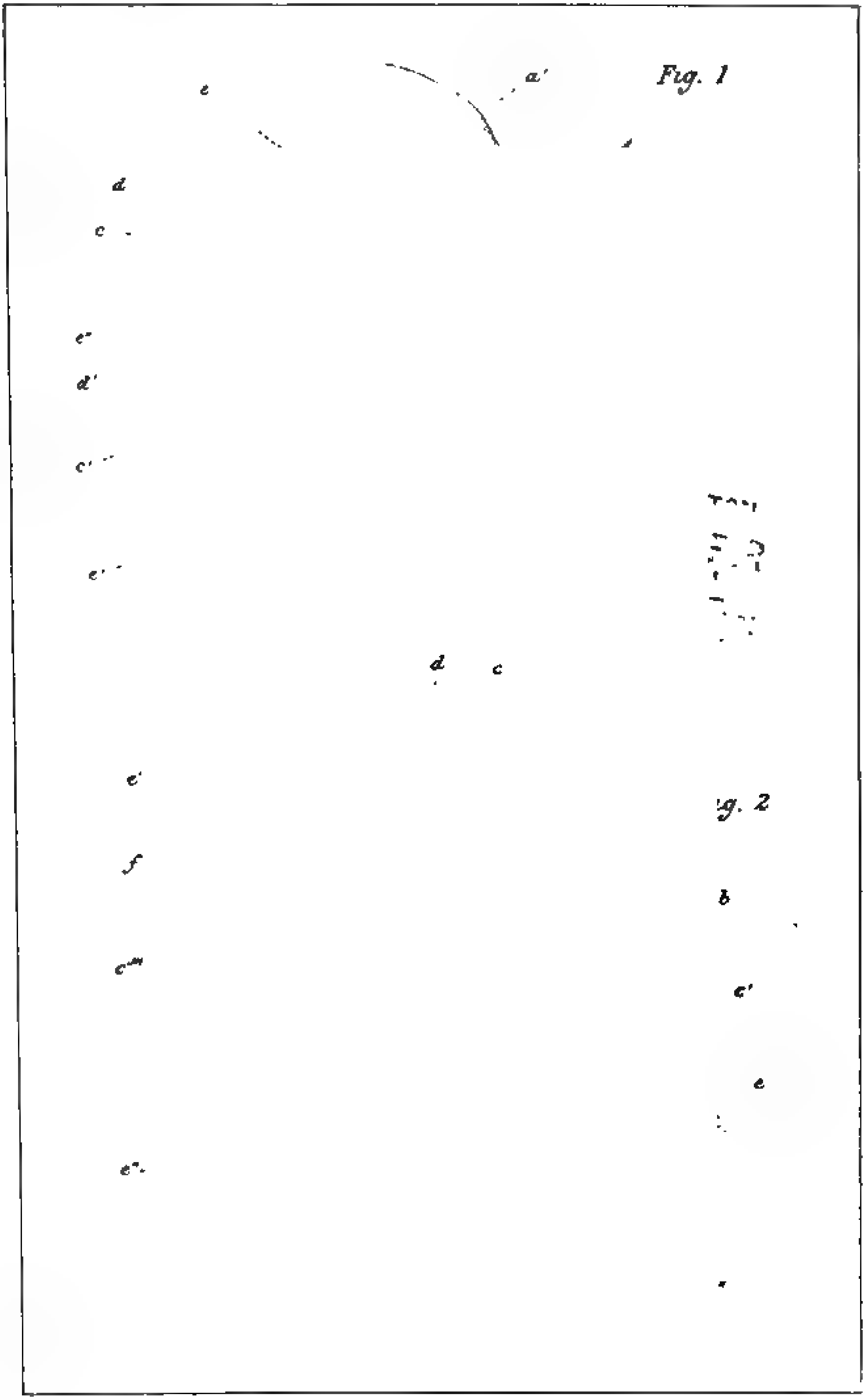

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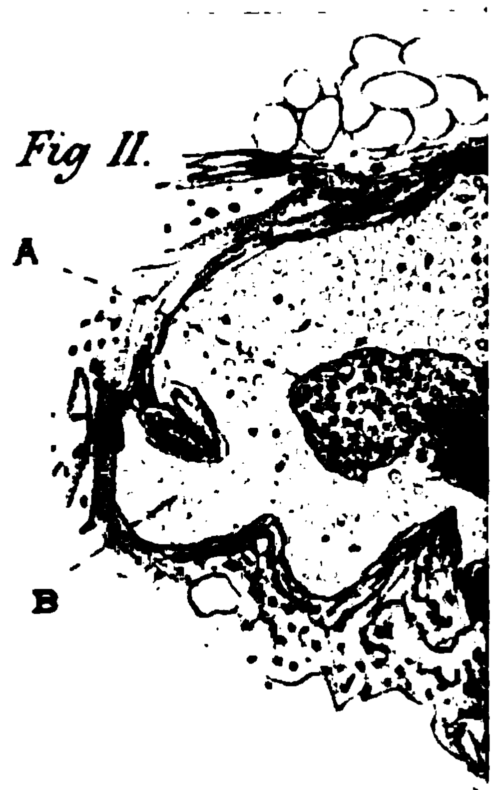

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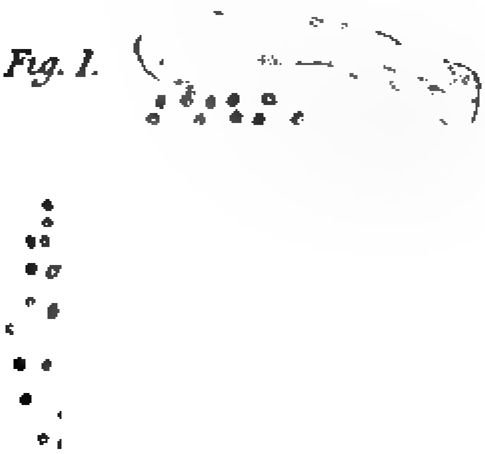

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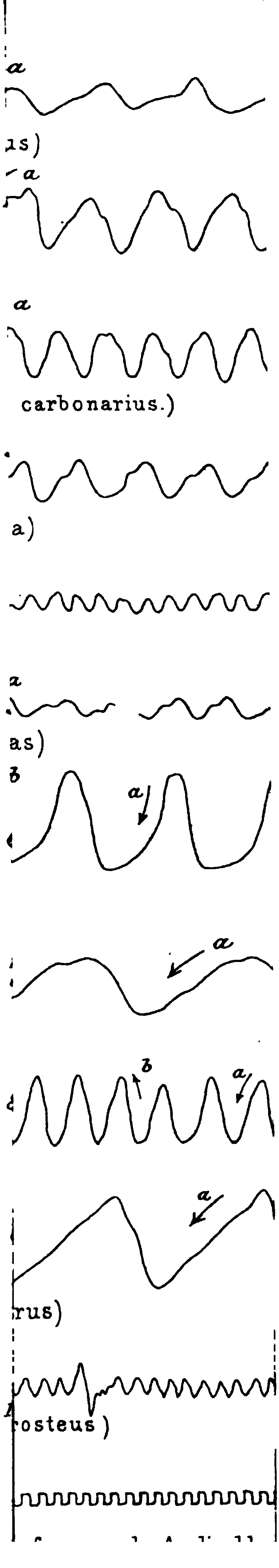
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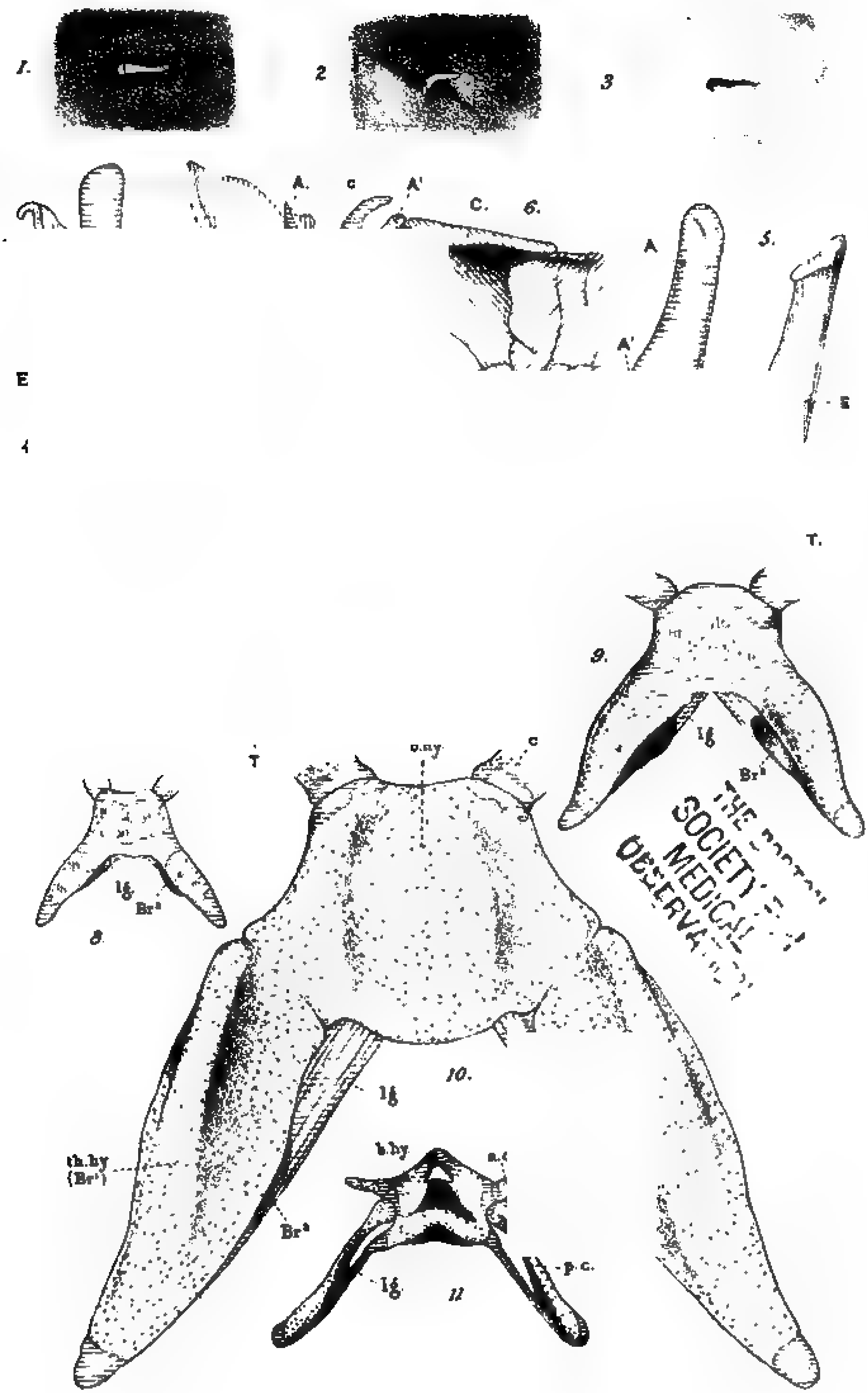

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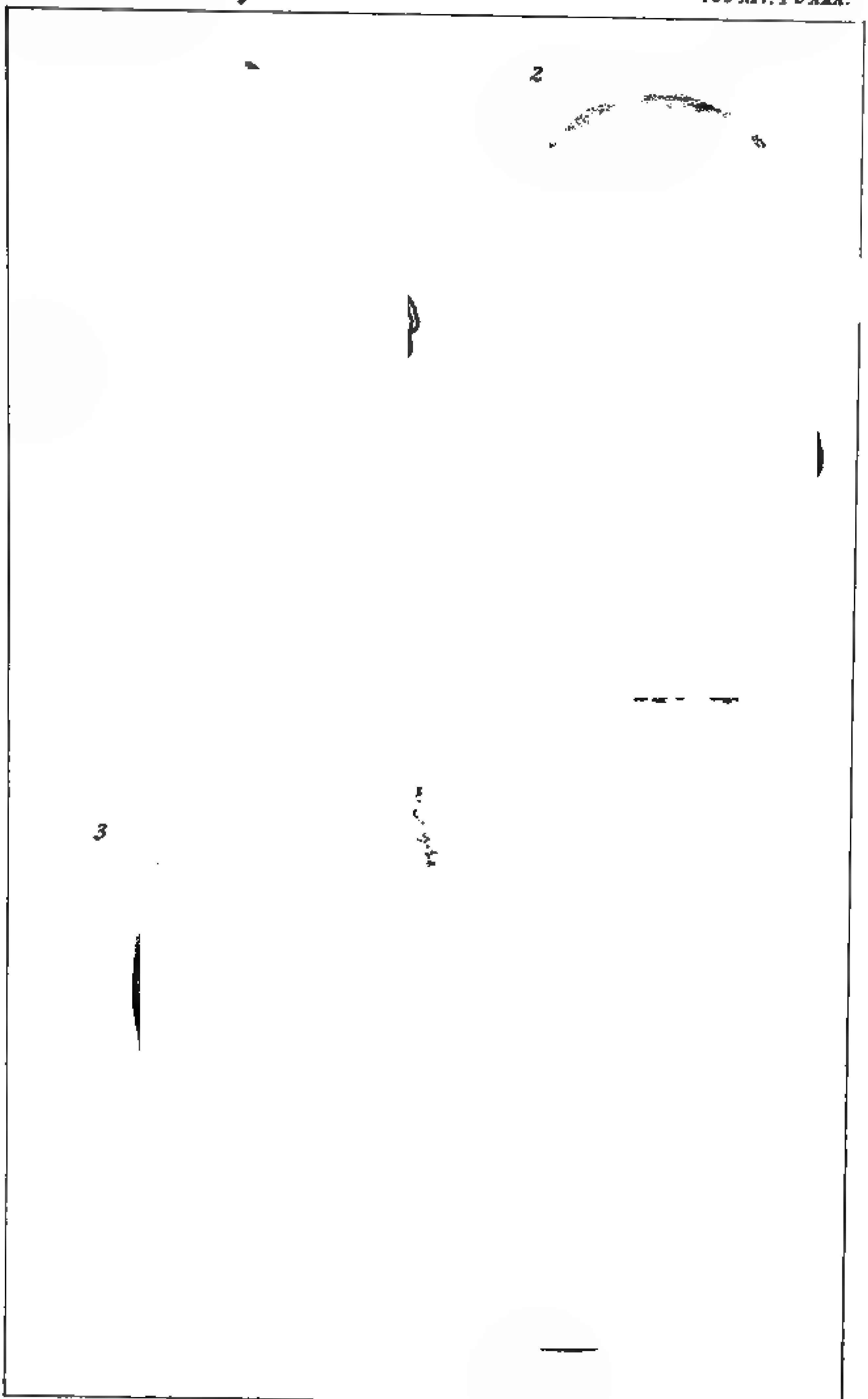

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